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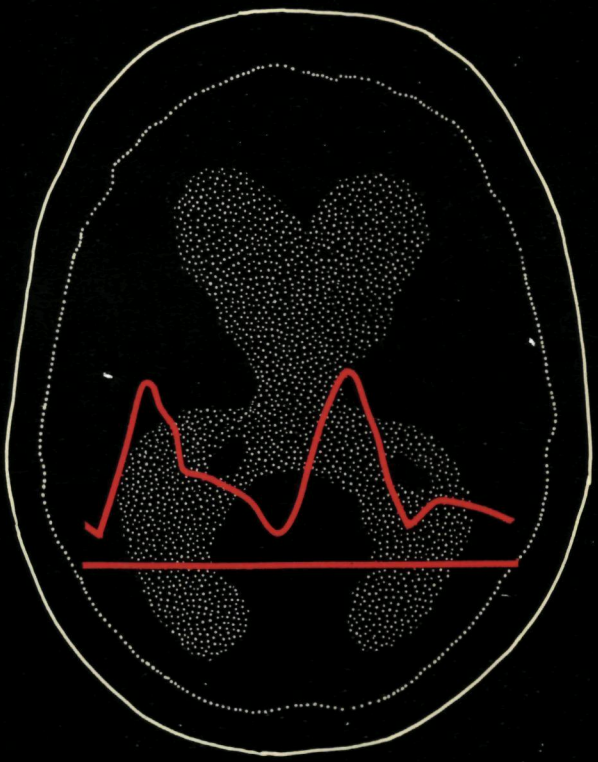
NORMAL PRESSURE HYDROCEPHALUS



THE DOPPLER-LP TEST AND OTHER SELECTION CRITERIA FOR SHUNTING

H.C. SCHOONDERWALDT

NORMAL PRESSURE HYDROCEPHALUS
The Doppler-LP test and other selection criteria for shunting

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CONTENTS

ABBREVIATIONS

ADL : activities of daily living
$ApCO_2$: alveolar carbon dioxide tension
BFC : blood flow through carotid artery
BFV : blood flow velocity
CA : cortical atrophy
CBF : cerebral blood flow
CBV : cerebral blood volume
rCBF : regional cerebral blood flow
rCBV : regional cerebral blood volume
CCA : common carotid artery
CH : communicating hydrocephalus
CSF : cerebrospinal fluid
CSFP : cerebrospinal fluid pressure
CNS : central nervous system
CT : computerized tomography (brain)
EDPM : epidural (extradural) pressure monitoring
ECG : electrocardiography
EEG : electroencephalography
F : female
FIRDA : frontal intermittent delta activity
5-HIAA : 5-hydroxyindolacetic acid
HTG : haematotachography
HVA : homovanillic acid
ICP : intracranial pressure
ICPM : intracranial pressure monitoring
LP : lumbar puncture
M : male
MABP : mean arterial blood pressure
MS : multiple sclerosis
n : number of patients
nd : not determined
np : not performed
NPH : normal pressure hydrocephalus
p : probability of statistical significance
PEG : pneumoencephalography
pvo : periventricular oedema
RIHSA : RIHSA cisternography
SAH : subarachnoid haemorrhage
SSEP : somatosensory evoked potential
VA shunt: ventriculoatrial shunt
VP shunt: ventriculoperitoneal shunt
X^2 test : chi-square test

Chapter I

INTRODUCTION

The recognition of the syndrome of normal pressure hydrocephalus (NPH) as a potentially treatable cause of dementia has had wide attention in recent years.

Although the occurrence of the delayed onset of hydrocephalus following subarachnoid haemorrhage had been reported earlier (Foltz and Ward 1956, Kibler et al. 1961), the syndrome was first described by Hakim (1964) and by Hakim and Adams (1965) as an occult form of communicating hydrocephalus in which the occurrence of intracranial hypertension was either absent or not recognizable. The patients have no evident signs of increased intracranial pressure, that is, they have normal optic disks and normal cerebrospinal fluid pressure ($\leq$20 cmH_2O) when having a routine diagnostic lumbar puncture, which is usually done in the daytime. Hakim and Adams stressed the importance of the clinical triad of dementia, gait disturbance and urinary incontinence when making the diagnosis. So the syndrome of NPH or Hakim-Adams syndrome is a clinical entity associated with ventricular enlargement and normal lumbar cerebrospinal fluid pressure. Paradoxically, despite the normal lumbar CSF pressure, all 6 patients of Hakim and Adams (1965) improved dramatically following the CSF shunting procedure.

As a result, a wave of enthusiasm for shunting demented patients followed. This initial enthusiasm, however, was soon followed by disappointment as it became clear that not all patients with dementia and ventricular enlargement benefited from CSF shunting. Today clinical features and several diagnostic procedures are not always reliable in differentiating NPH from dementias of other aetiologies. Furthermore, the diagnostic procedures commonly used now to establish the diagnosis of NPH often fail to predict which patients will respond to shunting.

Since 1965 many reports have appeared indicating very mixed results operating on such patients. It is important that a neurosurgeon should be in a position to ameliorate the condition of patients who are likely to improve and at the same time avoid surgery and possible complications in those patients who do tend to deteriorate due to a different disease process.

At the moment it is obvious that there is no single test which can be relied upon to predict the indications for or the results of shunting in patients with NPH. Each test has its proponents and yet each test has been clearly shown to be deficient in some respect. For example, radioisotope cisternography may still be helpful in some cases, but it is not reliable enough to serve as a basis either for selection or exclusion of patients for shunt therapy.

Nowadays special methods are available to predict shunt response by means of continuous intracranial pressure monitoring and special infusion tests. Up to now the value of these tests has still not been proved (Adams 1980, Belloni et al. 1976, Hartmann and Alberti 1977).

Studies of cerebral blood flow (CBF) in patients with NPH have suggested that there is a defect in CBF autoregulation (Greitz 1969 and Greitz et al. 1969). Raichle et al. (1974) and Mathew et al. (1975) have presented series of patients with NPH who showed improvement as well in regional CBF as in regional cerebral blood volume after CSF removal, but patients with cerebral atrophy showed no such response. If the increase in CBF was 15% or more, than the patients recovered excellently after shunting. The studies were done with the Xenon intra-arterial radioisotope method of Lassen and Ingvar (1961).

These reports induced us to measure the blood flow velocity in the common carotid artery in patients with NPH by way of Doppler sonography before and after CSF removal by lumbar puncture (Schoonderwaldt et al. 1978, 1981). The "Doppler-LP test" is a simple and innocuous test and in this thesis the value of this test in predicting the clinical outcome of CSF shunting in patients with NPH will be studied.

The results of the "Doppler-LP test" will be compared with results of other tests such as isotope cisternography, CT scan, intracranial pressure monitoring and with the clinical features. A review of the literature concerning several aspects of the NPH syndrome will be given; pathophysiological considerations will be discussed, especially concerning the hypothesis of a disturbance of CBF-CSF pressure autoregulation.

Chapter II

DESCRIPTION OF THE SYNDROME OF NORMAL PRESSURE HYDROCEPHALUS

A LITERATURE REVIEW

The term hydrocephalus refers to a diffuse pathological enlargement of the ventricular system within the brain secondary to an increased amount of CSF which results from an unbalance of production and absorption of the CSF. Hydrocephalus has been described by Hippocrates and he advised decompression as a treatment (McHenry 1969).

According to conventional terminology, hydrocephalus may be divided into obstructive and non-obstructive forms, or into communicating and non-communicating forms (Table I). In obstructive hydrocephalus there is a block to the free circulation of the CSF which has led to ventricular enlargement; in non-obstructive forms the enlargement is secondary to atrophy of the brain substance as in the (pre)senile dementias (also termed "hydrocephalus ex vacuo"). Most forms of obstructive hydrocephalus are "non-communicating" in the sense that the ventricles do no communicate freely with the subarachnoid space, whereas in communicating hydrocephalus such communication is free. An important variety, however, is at the same time obstructive but still communicating. Here the block is not within the ventricular system but in the subarachnoid space, allowing free egress of the cerebrospinal fluid from the ventricles but preventing its subsequent upward flow over the surface of the hemispheres for absorption at the superior sagittal sinus. In such cases the block is usually situated in the basal cisterns of the brain. It is very often associated with normal pressure within the ventricular system. Such a syndrome has been variously termed normal pressure hydrocephalus but also, symptomatic occult hydrocephalus (Adams et al. 1965), low pressure hydrocephalus (Taveras 1968, Greitz 1969), normotensive hydrocephalus, communicating hydrocephalus and hydrocephalic dementia (McHugh and Goodell 1966).

None of these terms is entirely satisfactory. The pressure is not always normal, occult hydrocephalus is also used for any hydrocephalus in which the head is not enlarged, communicating hydrocephalus also comprises hydrocephalus ex vacuo. Greitz (1969) suggested the term brain distension in the mild cases and low-pressure hydrocephalus in cases with strong symptoms.

It has long been recognized that hydrocephalus may, especially in adults, lead to dementia, disturbances of gait and consciousness, and ultimately to death. From time to time the occurrence of progressive hydrocephalus in the presence of normal pressure has been noted.

For example, in 1935 Penfield wrote: "It should be pointed out that an occasional exceptional case is encountered in which the cerebrospinal fluid

spaces are closed and the ventricles progressively enlarge without the measured intraventricular pressure rising above 150-200 mm of water". In 1956 Foltz and Ward recorded the first instance in which a patient with NPH due to subarachnoid haemorrhage, responded to shunting and two years later Clarke and Laidlaw (1958) recorded another instance of adult hydrocephalus with normal pressure. We owe to Hakim (1964) the recognition that it is not the occasional, exceptional case in which hydrocephalus in the adult occurs without increase in intracranial pressure. He identified NPH as a clinical entity and a cause for a reversible dementia and in collaboration with Adams (Hakim and Adams 1965, Adams et al. 1965) he further elaborated the description.

In this thesis the syndrome of NPH will be defined as a clinical syndrome of dementia, gait disturbances and with or without urinary incontinence associated with ventricular enlargement and normal CSF pressure ($\leq$ 20 cmH_2O) (found by lumbar puncture, which is usually done in the daytime).

2. PREVALENCE OF NPH AND AGE OF INCIDENCE

There is no precise knowledge of the prevalence of NPH. Despite the large and expanding number of case reports, only an attempt at guessing the frequency of this syndrome can be made. Regarding the idiopathic form of NPH, Marsden and Harrison (1972) found a frequency of approximately 6% in 86 patients with presenile dementia. In the study of Katzman (1977) the diagnosis was made in 3 of 56 patients with dementia; again a frequency of about 5%. In both studies, the patients were under 70. Its incidence and natural history in the aged are largely unknown. In the Jellinger series (1976) of 1009 autopsies on demented patients, hydrocephalus occurred in 4% of those under the age of 70, but in less than 1% in persons over 70 (4 cases among 846 senile dements over 70). By the end of 1975, it was possible to compile reports of 914 cases of NPH in adults, 314 of which (34%) were of the idiopathic form (Katzman 1977) (Table II). Thus the idiopathic form of NPH is not a common condition, although its significance within the spectrum of dementias is greater than its relative prevalence because of its potential treatability.

Looking at the age at which idiopathic NPH occurs it is evident that the diagnosis is usually made in the presenium, with a peak in the late 50.s (Katzman 1977) (Fig. I). However, this peak is likely to be an artefact due to the less intensive investigation of older dements and the difficulty in

distinguishing between NPH and Alzheimer's disease. Smith and Kiloh (1981) found among 164 patients with dementing illnesses 8 patients with NPH (4.9%); 7 of these were in the 45-64 age group (n=96) which makes 7.3% and 1 patient was aged 66 (n=53) which makes 1.9% of the age group over 65.

3. AETIOLOGY OF NPH

Various aetiologies for NPH have been put forward. Bannister et al. (1967) using radionuclide cisternography demonstrated obstruction of CSF flow in 8 out of 14 patients with the NPH or Hakim-Adams syndrome. They proposed that the cause of the syndrome was the obstruction of CSF flow over the brain convexity probably secondary to trauma, subarachnoid haemorrhage or meningitis.

So 2 groups of patients with NPH have been identified. In one group of adults of varying age the disorder is secondary to previous headtrauma, subarachnoid haemorrhage or meningitis; whereas in the other group, often designated idiopathic NPH, the cause is not apparent.

Subarachnoid haemorrhage

After subarachnoid haemorrhage (SAH), organization of exudate within the arachnoid villi at the superior sagittal sinus may contribute further by obstruction of the reabsorption of CSF (Ellington and Margolis 1969). SAH is the most frequent cause of hydrocephalus in adults, accounting for approximately 35% of the patients with NPH (Table II). An acute communicating hydrocephalus occurs in about 10% of patients with bleeding aneurysms at the time of hospital admission (Raimondi and Torres 1973). Studies of serial angiograms suggest the incidence of hydrocephalus in patients with SAH to be about one-third (Galera and Greitz 1970, Griffith et al. 1972) but the incidence of symptomatic hydrocephalus persisting after haemorrhage is about 10% (Yasargil et al. 1973, Theander and Granholm 1967).

It is often difficult to distinguish between symptoms due to acute hydrocephalus and symptoms secondary to SAH. The presence of a decreased level of consciousness, convulsions, agitation and pyramidal signs in these patients is qualitatively not different from the constellation of symptoms observed in others with SAH without hydrocephalus.

In the more typical instance, communicating hydrocephalus is recognized when, after some improvement in the patient's condition following either the initial haemorrhage or a reparative operative procedure, the patient's condition deteriorates. In other instances, however, there may be a significant delay between the ictus and the onset of hydrocephalic symptoms. Theander and Granholm (1967) reported on a group of 5 patients with hydrocephalus persisting a year or more after SAH before giving symptoms.

In itself ventricular enlargement without symptoms should not necessarily lead to shunt therapy, since the hydrocephalus might arrest spontaneously; but if ventricular enlargement were present, more frequent follow-ups to determine whether the process is progressing or receding would be warranted.

Headtrauma

Of the 3 patients initially reported by Hakim in his thesis (1964), 2 were patients who had signs of NPH after headtrauma, with reversal symptoms after shunting. The neurological symptoms in these patients were more flagrant than in those with idiopathic NPH and included akinetic mute states and tetraparesis.

The frequency of NPH after headtrauma is probably low considering the high incidence of headtrauma and the limited number of cases in which NPH is reported.

Of cases of hydrocephalus in adults culled from the literature, (Table II) only 11% were reportedly due to headtrauma.

When the headtrauma is severe and probable or verified hydrocephalus is identified, the clinician has a basis on which to associate the two conditions.

Because of the high incidence of mild to moderate headtrauma in the population, however, it is impossible to ascertain whether a previous mild headtrauma is related to a patient's NPH.

The mechanism by which headtrauma produces NPH may involve SAH at the time of injury in at least some patients (Hill et al. 1967).

In those in whom the post-traumatic symptomatology and the symptomatology due to the hydrocephalus merge, the diagnosis is usually suspected when the patient has shown some recovery and then deteriorates. There may be a significant interval however, between the headtrauma and the clinical syndrome of hydrocephalus.

Meningitis

Meningitis may produce NPH during the acute phase by clumping of purulent fluid in the drainage channels, and in the chronic phase by organization of exudate and blood resulting in fibrosis of the subarachnoid spaces (Voris 1955).

As a rule bacterial meningitis tends to produce cerebral cortical arachnitis, while granulomatous or parasitic meningitis produces cisternal obstruction. Seldom will viral meningitis result in obstruction at either point.

Abnormalities in parasellar region or posterior fossa

In very few instances the typical clinical syndrome of NPH may be due to a partially non-communicating hydrocephalus caused, for example, by a third ventricular tumour or aqueductal stenosis. NPH may occur subsequent to an intraspinal or intracranial operation; particularly one in the parasellar region or in the posterior fossa.

Riddoch (1936) found in a patient with profound dementia due to hydrocephalus above a colloid cyst of the third ventricle a pressure of only 160 mm H_2O in the lumbar subarachnoid.

Aleksic and George (1973) reported a patient with pituitary adenoma, who showed symptoms of dementia and low pressure hydrocephalus. The adenoma had compressed the foramen of Monro on one side. At operation, the pressure in the involved ventricle was only 85 mmH_2O. Following surgery for posterior fossa tumours Stein et al. (1972) observed in 3 children deterioration associated with progressive enlargement of the lateral ventricle, with normal intracranial pressure.

Malignancies

Diffuse meningeal malignancy due to carcinoma, lymphoma or leukemia, though uncommon, can cause hydrocephalus by obstruction of the liquor drainage at the level of the arachnoidal villi and dural sinuses by the invasion of cells into these structures. It is shown that even in a case of preventive brain irradiation and intrathecally administered cytotoxic drugs, these structures remain areas in which the leukemic cells are difficult to destroy (De Reuck

et al. 1979).

Arachnoid cysts

Another cause of hydrocephalus, though uncommon, is an extra-axial arachnoid cyst which may be located in the basal cisterns or over the cerebral cortex. The cyst traps CSF without allowing full drainage into the sinuses. As it enlarges it will eventually produce extrinsic compression of the ventricular system or of the subarachnoid channels.

In the study of Katzman (1977), 33% of the patients with NPH had the idiopathic form (Table II). It is surprising that we should still speak of idiopathic NPH and cannot be more precise as to aetiology when more than 300 patients have been reported in the literature, and these reports indicate that many have not survived. However, autopsy material which might lead to a better understanding of the disorder has not been frequently reported (see Chapter II.4).

4. NEUROPATHOLOGICAL ASPECTS OF NPH

Morphologically, the syndrome of secondary NPH is associated with thickening of the pia-arachnoid at the base or over the convexities following meningitis, cranio-cerebral injury or subarachnoid haemorrhage. After subarachnoid haemorrhage, organization of exudate within the arachnoid villi at the superior sagittal sinus may contribute further by obstructing the reabsorption of CSF (Ellington and Margolis 1969). The mechanism by which headtrauma produces NPH may involve subarachnoid haemorrhage at the time of injury in at least some patients (Hill et al. 1967).

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Ross et al. (1982) described a child with nephropathic cystinosis (Fanconi syndrome) who developed communicating hydrocephalus. A meningeal and brain biopsy was obtained during placement of a ventricular peritoneal shunt. Anisotropic crystals consistent with cystine were demonstrated in biopsy samples of arachnoid and cerebral cortex. The hydrocephalus in this child may have resulted from deposition of cystine in the meninges which interfered with CSF absorption.

Few post-mortem examinations of the idiopathic NPH cases have been reported.

Adams (1975) suggested that a "low-grade asymptomatic meningeal disease, possibly inflammation of undetermined etiology" was the basis of most cases of idiopathic NPH. Arachnoid thickening was reported by DeLand et al. (1972), Vessal et al. (1974) and Jellinger (1976) in 14 autopsy cases of NPH. It should be noted, however, that 5 of these patients had severe cerebrovascular disease in addition. Katzman (1976) reported one patient with NPH and marked thickening of the arachnoid in the presence of normal cortical architecture as observed on a cerebral biopsy. In another patient, however, there was only mild meningeal thickening.

Leptomeningeal fibrosis was also reported by Heinz et al. (1970), Sypert et al. (1973) and Ribadeau-Dumas et al. (1976).

As in the 3 patients described by Di Rocco et al. (1977), a certain degree of leptomeningeal fibrosis was present. However, the subarachnoid space appeared still to be patent.

Not much attention has been paid to the study of arachnoid villi in NPH. Cushing (1926) mentioned that the hydrocephalus in some of his patients could be attributed to an "absence of arachnoidal projections or villi". Winkelman and Fay (1930) described 14 instances of aplasia of arachnoid villi, but in only 3 there was hydrocephalus. He also described hypoplasia, fibrosis, inflammation by inflammatory cells in meningitis and neoplastic cells.

Gilles and Davidson (1971) presented two hydrocephalic children; one with absence of parasagittal arachnoidal granulations, the other with a markedly diminished number of arachnoidal granulations. In these patients no other

causes for the ventricular dilatation were found.

While it is clear that the abnormality of arachnoidal granulations may have arisen from either failure of development or subsequent destructions of pre-existing granulations, no evidence for the latter was found in Gilles and Davidson's patients (1971).

In the literature there are 3 autopsy cases suggesting a causal role of cerebrovascular insufficiency, two cases described by Earnest et al. (1974) and one described by Coblentz et al. (1973). Earnest et al. (1974) reported 2 patients with normal leptomeninges and arachnoidal villi but with hypertensive vascular disease and multiple deep cerebral infarcts, who had been presented with clinical and radiological criteria consistent with idiopathic NPH. One of these patients improved with shunting. An unexpectedly high incidence of hypertensive cerebrovascular disease was found by Vessal et al. (1974), 4 of the 5 patients had significant cerebrovascular diseases in addition to arachnoidal fibrosis.

Stein and Langfitt (1974) reported 3 patients who had a positive response to shunting as well as typical clinical and laboratory presentations. In 2 patients the biopsies were normal, and the third patient showed microvasculature changes of hypertension. These authors also reported 12 biopsies in patients who did not respond to shunts; 6 patients had Alzheimer's changes, 3 patients showed non-specific cortical atrophy and 3 patients were normal.

Ball and Vis (1978) did quantitative morphometry on 5 brains of elderly patients (aged 57-78) with NPH to determine the degree of granulovacuolar degeneration in hippocampal neurones. The severity of this change was not attributable merely to ageing, being greater in the four unimproved cases than it was in age-matched control brains from 18 normal subjects, and falling in the same elevated range as that of 8 dements with necropsy-confirmed Alzheimer's disease. The intensity of granular degeneration in the one shunted dement who improved was within normal limits. A positive linear correlation existed between the granulovacuolar indices and the total duration of dementia. These data suggest that earlier diagnosis may improve the chances of reversing dementia in NPH syndromes before histopathology is too severe; and that a more careful search for features of NPH may be warranted in some cases of Alzheimer's dementia.

In the literature there are a few reports of patients with Alzheimer's disease who are said to have improved after shunt therapy (Sohn et al. 1973, Coblentz et al. 1973, Lytmaer et al. 1976). However, one might easily put forward that the pathological findings indicating vascular insufficiency and

Alzheimer's disease do not necessarily imply that such a pathology is the causal factor of the NPH. It might be a concomitant event.

Furthermore, the great majority of patients suffering from cerebral vascular insufficiency or Alzheimer's disease do not develop NPH. A rare cause of NPH was described by Breig et al. (1967) and by Ekbom et al. (1969); in hypertensive individuals an elongated, ectatic basilar artery may indent the floor of the third ventricle and distort the ventricular system upwards and anteriorly, leading to NPH.

Barbosa et al. (1979) found in 2 patients with NPH nuclear bodies. Simple nuclear bodies were found in all layers of the cortex and white matter, whereas complex ones were only seen in the fifth and sixth layers and in the underlying white matter. The presence of nuclear bodies with the same morphological features of those described were found principally in cortical biopsy specimens from patients with proved or supposed diseases of viral aetiology (Martinez et al. 1974, Grunnet 1975, Bouteille et al. 1967).

In view of this and considering that the pathogenetic mechanisms of NPH, although numerous, have not yet been clearly defined, it is tempting to suggest that a chronic viral infection might be present in these 2 patients.

A pathological finding which appears interesting in discussing the possible pathogenetic mechanisms of NPH is that of the periventricular white matter oedema with spongiosis, a finding common in all 3 patients described by Di Rocco et al. (1977). Common neuropathological findings in the 3 patients were: leptomeningeal non-obstructive fibrosis, ventricular ependymal disruption, subependymal glial reaction, periventricular demyelination and spongiosis.

The finding of oedema with spongiosis was likely to be due to leakage of CSF from the ventricles into the cerebral parenchyma and it can be regarded as an alternate route of absorption of the CSF. The severe disruption of the ventricular ependymal wall would favour this explanation. Price et al., too, (1976) found that during the evolution of hydrocephalus the structure of the ventricular walls is changing strikingly. Price et al. (1976) produced chronic communicating hydrocephalus in adult dogs by injection of silastic into the subarachnoid space. The serial pathologic changes were correlated with cisternography. Silastic is inert and does not cause an inflammatory reaction. The ependymal cells are attenuated and have fewer cilia and microvilli. Extracellular fluid accumulates at their lateral margins. The flattening of these cells presumably results from increased intra-ventricular pressure during the development of early hydrocephalus. It is likely that the tensile

properties of the ependymal cells alter. Reduction in tensile strength of the ependyma may eventually result in a decline in intra-ventricular pressure.

The escape of CSF from the ventricles into the cerebral parenchyma does occur in human and experimental hypertensive hydrocephalus (Milhorat et al. 1970, Price et al. 1976).

In these cases the different pressure gradients on the 2 sides of the ventricular wall are due to the abnormal increase in the CSF pressure.

The findings of continuous intracranial pressure recordings indicate that in NPH the CSF pressure might undergo abnormally high oscillations. A pathogenetic role of these high pressure oscillations has been suggested.

The escape of CSF is greatest in areas where damage to the ependyma and subependyma is greatest (in particular angles of the lateral ventricles) (Milhorat et al. 1971). Accompanying these morphological changes there is an increased migration of intra-ventricular dyes into the surrounding brain (Milhorat et al. 1970).

The basic cause of NPH seems to be a block of normal CSF flow, the origin and results of which, however, cannot always be elucidated by current neuropathological methods.

In this context it is of interest to mention the findings of Inzitari et al. (1985). They reported an abnormal isotope cisternography pattern in 25 patients (38.5%) of a group of 65 definite multiple sclerosis patients. The tracer filled the ventricular system within 2-6 hours after lumbar injection. After 24 hours there was little or no activity within the ventricles, the flow over the convexities was normal but the reabsorption at the vault was slower than in normal pictures. An abnormal isotope cisternogram was significantly more frequent among patients with chronic-progressive and "malignant" course and among those with a higher disability score. The pathological processes that may be involved in the modification of the CSF dynamics in MS are: (1) cerebral atrophy, (2) chronic inflammation of leptomeninges with partial subarachnoid block, (3) periventricular tissue modification with increased transependymal flow.

5. CLINICAL FEATURES (Table III)

Although Adams et al. (1965) described a rather characteristic clinical syndrome, formed by the triad of progressive dementia, spastic ataxic gait and incontinence, it is apparent from the large number of patients reported as

responding to shunting that the clinical findings in NPH are quite variable (Benson et al. 1970, Ojemann et al. 1969, Rice et al. 1973, Sypert et al. 1973). The symptoms between individual patients vary rather widely. A considerable variation in degree of deranged mental function and motor abnormality is noted.

In the years after the original description of the NPH syndrome, the emphasis was on dementia as a diagnostic criterion rather than on gait disturbance and urinary incontinence. Ojemann et al. (1969) mentioned that gait disorder could precede other symptoms and so did Chawla and Woodward (1972). Adams (1975) stated that each of his 50 patients diagnosed as NPH over a ten year period had unsteadiness of gait associated with deterioration of mental functions. Fisher (1977) found in his group of 16 successfully shunted patients that the predominant and most constant symptom or sign is a disturbance of walking and standing. A change in mentation may accompany or follow gait disturbance but not precede it; so did also Guidetti and Gagliardi (1980) in their group of 38 patients. Børgesen and Gjerris (1982) found gait disturbances in 79 out of a total of 80 patients and urinary incontinence was present in 52 patients, while dementia to some degree was present in all patients. Fisher (1978, 1982) stressed that gait disturbance is often the only obvious symptom of NPH.

Although initial reports tended to emphasize memory disorder as the primary symptom, subsequent evaluation has confirmed gait disturbance as the usually prominent clinical feature.

Movement disorder

Although there are some patients without gait disturbances who have responded to shunting (Jacobs et al. 1976, Stein and Langfitt 1974), there is little doubt that gait impairment is a hallmark of the typical syndrome. Some investigators claim that patients with gait disturbances are likely to be the best candidates for shunting (Benson et al. 1970, Jacobs et al. 1976, Katzman 1974, Messert and Wannamaker 1974, Fisher 1977).

The gait disturbance may take many forms. Often there is an element of spasticity with increased deep tendon reflexes in the legs and bilateral Babinski signs. These paraplegia and reflex changes are postulated as being due to compressing and stretching of the long descending fibre tracts extending from the cortex of the frontal lobe as they sweep past the dilated fron-

tal horns of the lateral ventricles coursing to the legs. In contrast the descending fibres involved in face and arm movements, separated from the ventricle and protected by the body of the caudate, are thus relatively spared the stretching by the hydrocephalic dilatation of the lateral ventricles (Yakovlev 1947).

In mild examples the patients walks slowly on a broad base with a stiff-legged shuffling gait. Unsteadiness which is made worse on attempts at tandem walking occurs about as frequently as spasticity. Messert and Baker (1966) pointed out the frequency of a combined spastic ataxic gait in NPH. The spasticity is not usually associated with weakness on muscle testing nor is the ataxia due to a cerebellar disturbance. In addition to the spastic ataxia, the patients have commonly but not always difficulty in initiating movement of a standing position, with turning, and they often fall backwards. Sometimes the feet appear "glued" to the floor as if held by a "magnet".

Botez et al. (1975) found that one of the early signs in NPH is a tonic pressor and grasp reflex of the foot which may be related to the appearance of the "magnet" gait. Again, these symptoms have been attributed to frontal lobe disturbance secondary to ventricular dilatation. In some patients the difficulty in initiating movements may closely resemble the bradykinesia in Parkinsonism and many instances are cited in the literature in which patients have initially been diagnosed as having Parkinson's disease.

To the symptoms of NPH a Parkinsonian movement disorder must now be added. Other movement features may include slowness of movement in the upper limbs or occasionally some degree of arm tremor or ataxia.

Dementia

The dementia of NPH is often described as mild and of insidious onset. The mental changes range from mild memory disturbance or apathy to severe psychomotor retardation and profound intellectual impairment.

Forgetfulness is usually a prominent early feature, combined with slowing of mental and physical activity, difficulty with thinking and reduced spontaneity, a combination which may lead to a diagnosis of early presenile dementia or depression. The emotional reactions are less vivid and psychic life seems generally impoverished. Insight is limited or absent from an early stage but social behaviour is usually well preserved.

Benson et al. (1970) noted: "In the early stages, apathy is more striking

than depression of cognitive ability".

Even the reduction in performance observed early in this disorder may be secondary to slowness on timed tasks, rather than to true cognitive, perceptual or constructional dysfunction and in this respect be similar to other "subcortical dementias".

With progression of the disorder the patient becomes increasingly disorientated, calculation is impairing, and dysphasia and disturbances of writing and drawing may develop.

However, aphasia and other specific cortical defects are not ordinarily encountered. Memory impairment may ultimately be as severe as that seen in Korsakoff's psychosis, or the global dementia virtually indistinguishable from that of Alzheimer's disease or senile dementia.

Incontinence

Urinary incontinence is reported as a frequent occurrence in a late stage of the disorder, but may set in surprisingly early in relation to the degree of mental impairment. This symptom may not be helpful in differentiating patients with NPH from those with Alzheimer's or other progressive presenile or senile dementias, because urinary incontinence is a frequent accompaniment of these disorders also. Faecal incontinence may rarely occur; it will develop only in the most severe examples.

Adams (1975) has suggested that patients actually suffer from "anosognosia of micturition" being unaware of their incontinence.

Disturbances of consciousness

Alteration in the state of consciousness is more often seen in hydrocephalus with increased intracranial pressure than in NPH. Nevertheless, some patients with NPH secondary to bleeding or trauma may develop lethargy, akinetic mutism or coma. In patiens with idiopathic NPH, akinetic mutism has sometimes occurred following pneumoencephalography.

Psychiatric symptoms

Mostly, patients with NPH are quiet, withdrawn and slow, but occasionally, patients are irrational, paranoid and agressive (Crowell 1976, Rice and Gendelman 1973). Rice and Gendelman (1973) suggested that symptoms such as anxiety, delusional thinking, ideas of reference, visual hallucinations and mood and personality changes are related to prior emotional problems and that these symptoms are not specific for hydrocephalus per se. However, it is important to know that psychiatric sequelae can be as well the predominant as the initial clinical manifestation of NPH. A relatively abrupt change in personality and the onset of psychiatric symptoms in a previously well-compensated person is a situation to be kept in mind before raising suspicion about the presence of NPH, mostly idiopathic in origin. Depression is reported frequently to accompany NPH.

In some cases there may in fact be a "pseudo-depression" resulting in the slowing of psychological processes and misinterpreted as a depression. In other instances, however, patients have expressed depressive thoughts which have sometimes persisted following shunting (Adams 1975). There is the possibility that in some patients shunting may ameliorate a depression, in particular in some patients with Alzheimer's disease and enlarged ventricles in whom transient improvement following shunting has been observed. Rosen and Swigar (1976) described a 55-year-old woman with NPH who apparently had a severe agitated depression and who showed moderate improvement following shunting.

Additional findings

Headache is rare in NPH and when present usually minimal. A history of falling spells with brief impairment of consciousness is common, but frank epileptic seizures are not common.

In addition to bilateral Babinski's signs other abnormal reflexes such as Hoffmann's, grasp and snout reflexes can be observed. These are late sequelae of hydrocephalus. Unexplained nystagmus and disturbance of extra-ocular motility is occasionally present.

Trigeminal sensory symptoms associated with NPH were reported by Maurice-Williams and Pilling (1977). In 2 patients with trigeminal pain and in 1 with facial paraesthesia, the symptoms remitted with relief of the hydrocephalus

following shunting. The cause may be a stretching of the trigeminal sensory roots by distal displacement of the brainstem due to hydrocephalus. In a study of Jacobs (1977) 17 of 33 patients (51.5%) with NPH were discovered to have diabetes mellitus. This was significantly greater than the 12.1% incidence found in age-matched control subjects. Diabetes mellitus in NPH may be a result from involvement of hypothalamic and brainstem autonomic structures caused by the expanding ventricles.

Clinical course

The course without treatment is of a slow downward progression with increasing neurological and mental disability. Fluctuations from day to day or from week to week can occur.

In some of the more prolonged examples a plateau appears to be reached after many months with a relatively fixed pattern of impairment thereafter (Hughes et al. 1978). Others progress eventually to coma and death.

6. DIFFERENTIAL DIAGNOSIS

The most important differential diagnoses of NPH are the primary senile and presenile dementias. McHugh and Goodell (1966) suggest that the NPH syndrome should be considered in any individual who is declining mentally, particularly if the illness has taken a subacute course over months rather than years. It should be considered highly suspected if early in the decline there appears a disorder of gait together with marked inertia, apathy and psychomotor retardation. Urinary incontinence developing before the mental impairments have proceeded very far, should also raise suspicion. A depressive illness may be simulated early in the course, when psychic and mental slowness are prominent and intellectual impairment is minimal. Rosen and Swigar (1976) emphasized the need to include NPH in the differential diagnosis of depression in the presenium

When the gait disturbance is the presenting feature, differentiation is required from other causes of mild spasticity and ataxia such as cervical spondylosis, vitamin B12 deficiency, multiple sclerosis, syphilis and hypothyroidism.

The gait dyspraxia often seen in patients with NPH may resemble the gait of Parkinson's disease.

However, a number of patients have been reported who, in addition, showed other Parkinsonian signs such as tremor, masked facies, cog-wheel rigidity, hypophonic speech and bradykinesia (Jacobs et al. 1976, Lin et al. 1968).

In these patients gait and mentation improved after shunt therapy, but the other Parkinsonian features remained. L-Dopa did prove beneficial; thus NPH and Parkinson's disease may have co-existed.

In contrast were the observations of Sypert et al. (1973) who studied 3 patients with clear-cut Parkinsonian features associated with NPH in whom both the dementia and the extrapyramidal movement disorder were relieved by shunting. On post-mortem examination, 1 patient was found to have a dense adhesive arachnitis obliterating the basilar cisterns and a chronic granular ependymitis resulting in a secondary aqueductal stenosis, both associated with a left anterior cerebral artery aneurysm which had been clipped during life. There were no changes in substantia nigra or basal ganglia that would suggest a true Parkinson's disease. The dramatic response of the Parkinsonism to shunting and the neuropathologic observation in this patient argue against the idea of a coincidence of two diseases (NPH and Parkinson's disease). It seems more likely that the Parkinsonism is secondary to the hydrocephalus.

Since the description of Sypert et al. (1973) the presence of occult NPH should be excluded in each patient with Parkinsonism-dementia complex before he is relegated to a hopeless category.

Spagna et al. (1978) described a 70-year-old woman with the triad of NPH, Parkinsonism and primary empty sella. Treatment with levodopa-carbidopa and ventriculo-jugular shunt resulted in a marked improvement. The syndrome may be the result of several mechanisms, but an alteration of CSF pressure dynamics may be the sole aetiology for this triad.

A major concern is the differential diagnosis of idiopathic NPH and Alzheimer's disease. In Alzheimer's disease the changes of muscular tension and the small step gait might sometimes cause difficulty in differential diagnosis. In studies of the histological verification of Alzheimer's disease Coblentz et al. (1973) found that many individuals had criteria consistent with the diagnosis of NPH. The explanation of false-positive diagnostic tests in favour of NPH is the presence of severely dilated ventricles in 10% of patients with Alzheimer's disease as was shown by Tomlinson et al. (1970).

The differential diagnosis can best be made at our present state of knowledge by the fact that a patient with Alzheimer's disease has a progressive dementia as his first symptom, whereas those with NPH ordinarily have a gait disturbance as their first symptom.

Brumback et al. (1978) described the NPH syndrome in 4 patients (10-32 years) having the recessively inherited Cockayne's syndrome. Previous necropsy studies in Cockayne's syndrome have shown severe, grossly observable thickening of the leptomeninges with collagenous connective tissue (Rowlatt 1969).

Seven cases have been reported of the concurrence of NPH and basilar impression due to Paget's disease (Goldhammer et al. 1979, Dohrmann and Elrick 1982). It has been suggested that in basilar impression due to Paget's disease an obstruction of the basal cisterns prevents the flow of CSF over the cerebral convexities (Culebras et al. 1974, Gottschalk 1973, Hens and van den Bergh 1979). Inoue et al. (1984) presented a 69-year-old man with herpes zoster ophthalmicus complicated by contralateral hemiplegia and NPH, which became prominent 5 months after the zoster infection. The NPH is considered to be caused by recurrent haemorrhage from extensive cerebral arteritis.

Riggs et al. (1985) described a 47-year-old woman with myotonic dystrophy and marked hydrocephalus on cranial CT. She was seen after 2 years of increasing memory loss and personality change, 1 year of urinary incontinence, and severe gait disturbance for 6 months. Radionuclide cisternogram was consistent with communicating hydrocephalus. A lumboperitoneal shunt was placed with marked improvement of mental status, urinary incontinence and gait disturbance.

Portenoy et al. (1984) were the first who described familial occurrence of idiopathic NPH. They reported shunt-responsive NPH in a 67-year-old man and in his 74-year-old sister. The difficulty evident in explaining this occurrence reveals again the inadequate understanding of the basic pathologic processes involved in this disorder.

8. DIAGNOSTIC PROCEDURES

8.1 Pneumoencephalography (lumbar air encephalography)

Normally, air has free access from the lumbar theca to both ventricles and to the cortical subarachnoid space. Communicating hydrocephalus is revealed by

the entry of air to the dilated ventricles only and by complete absence of air from the subarachnoid space. With cerebral atrophy air enters the widened cerebral sulci. So pneumoencephalography (PEG) has a functional aspect.

Because the PEG outlines both the ventricular and subarachnoid spaces it had been the most important procedure in the diagnosis of NPH before introduction of CT.

Adams et al. (1965) considered pneumoencephalography to be essential to the diagnosis of NPH.

The commonly described PEG findings in NPH are dilated lateral ventricles, enlarged basal cisterns and relative lack of air filling the subarachnoid spaces over the cortex, the so-called convexity air block.

Le May and New (1980) have pointed out that many patients with true communicating hydrocephalus show air, filling the Sylvian fissure and certain subfrontal sulci, and in series reported by Greitz and Grepe (1971) the presence of large intrahemispheric fissures on PEG was still attended with post-surgical improvement in half of the cases. It is probably fair to say that extensive filling of the subarachnoid space over the convexities rules out NPH (Benson 1974) and that the demonstration of an incisural block establishes the diagnosis of NPH. However, the numerous mixed pictures present in two-thirds of the cases referred for consideration as cases of NPH, render it impossible to accept the distribution of air as the sole criterium for shunting. Observations by Le May and New (1970) led to the suggestion that a corpus callosal angle less than 120 degrees is characteristic of NPH, while patients with hydrocephalus ex vacuo have angles of more than 120 degrees.

Observers have varied in their enthusiasm regarding the reliability and usefulness of each of these criteria. The classic PEG findings are not present in all patients who clinically have the syndrome of NPH (Staab et al. 1972, Wood et al. 1974) and conversely the same findings are occasionally present in patients with diffuse cerebral atrophy.

An example of this lack of specificity is the description of 5 patients with proven Alzheimer's disease who exhibited convexity air block on PEG (Coblentz et al. 1973).

Similar findings of aspecificity of PEG have been reported by Wood et al. (1974), Shenkin et al. (1975), Greitz and Grepe (1971), Stein and Langfitt (1974) and Black (1980).

Sjaastad et al. (1969) and Greitz (1971) considered the width of the temporal horn to be of great significance in the differential diagnosis of NPH and hydrocephalus ex vacuo, but further investigation (Stein and Langfitt

1974) has not confirmed this fact.

The radiological diagnosis of NPH by PEG is thus based on criteria which lack specificity. PEG findings compatible with NPH cannot predict the value of a shunting procedure. It should also be noted that this procedure has sometimes been followed by rapid deterioration in the patient's condition (Bannister 1972, Ojemann et al. 1969).

Rovit et al. (1972) reported progressive dilatation after PEG as a sign of NPH. They hypothesized that this phenomenon occurred because air replacing ventricular fluid caused a decreased resorption of CSF via the ventricular ependyma.

CT scan has had an enormous impact on the use of PEG, making it an infrequent procedure nowadays.

8.2 Cerebral angiography

Patients with NPH have no diagnostic features on angiography. Separation of thalamostriate vein from the midline on A.P. venous views, elevation and straightening of the pericallosal artery and changes in curvature of large Sylvian vessels reflect the ventricular enlargement. Angiography thus provided an alternative method for determining ventricular enlargement. Angiography may be used especially when it may provide additional useful information as, for example, in patients with SAH in whom a repeated angiogram gives vital data about the aneurysma, AV malformation as well as about ventricular size.

8.3.1 Radioisotope cisternography

Radioisotope cisternography with RISA, indium, technetium and metrizamide is a relatively safe procedure that in contrast to PEG provides information about the dynamics of CSF circulation and also precludes the observed post PEG deterioration associated with NPH.

The development of radio-iodinated serum albumin (^{131}I HSA=RISA) cisternography by Di Chiro in 1964 has had important consequences of interest in diagnosis of NPH. It is a relatively safe procedure, there being only a few reports of aseptic meningitis secondary to intrathecal RISA (Detmer and Blacker 1965, Nicol 1967, Dramov and Dubou 1971). More recently RISA has been

replaced by ^{111}Indium-DTPA with even less morbidity and with the same diagnostic results (Hosain et al. 1972).

Bannister et al. (1967) studied the use of this technique in investigating patients for NPH. He confirmed normal distribution of radioactivity seen in the basal cistern 1 to 4 hours after injection into the lumbar subarachnoid space; over the frontal poles and Sylvian fissura in 2 to 6 hours, over the convexity between 6 and 12 hours and accumulating at the sagittal sinus between 12 and 24 hours. After 24 hours the radioactivity should be virtually absent from the basal cisterns and distributed over the cerebral convexities or concentrated in the region of the sagittal sinus, fading by 48 hours (see Fig. II). Normally the radiopharmaceutical does not enter the ventricular system.

Cisternography may also yield additional information. Positive images (areas of retained isotope activity) are correlated with destructive focal cortical lesions such as post-traumatic encephalomalacia, atrophy secondary to degenerative and development disorders.

Except for many mixed patterns two basic patterns are observed in communicating hydrocephalus. In the first, rapid ventricular filling (reflux) is seen on the early views (max. after 3 hours) and later views (24-72 hours) reveal persistence (stase) of ventricular activity with little or no ascension of activity over the cerebral convexities. In the second pattern, relatively rapid ventricular filling is observed, but ventricular clearance is also rapid, so that little activity is seen in the ventricles after 24 to 36 hours. This second pattern is most commonly observed in patients with hydrocephalus ex vacuo (Fleming et al. 1972). Many authors accept the first pattern as a sine qua non for the diagnosis of NPH (Bannister et al. 1967, Benson et al. 1970, Heinz et al. 1970, Le May and New 1970, Mc Cullough et al. 1970, Williams et al. 1970, Ojemann 1971).

Nevertheless many patients with ventricular stasis do not improve with shunts and in some series this test has differentiated poorly between shunt responders and non-responders (Maira et al. 1975, Rau et al. 1974, Shenkin et al. 1973, Tator and Murray 1971, Wolinsky et al. 1973, Wood et al. 1974, Jacobs et al. 1976). It is also true that the absence of this typical picture need not be associated with the failure to respond to surgery. In his review of 80 patients, Salmon (1972) found RISA cisternography unreliable. He also found post-shunt improvement occurring in patients with normal scans, while others with the typical pattern were unchanged following surgery.

Stasis occurs in some patients with proven Alzheimer's disease (Coblentz

et al. 1973) or cerebral atrophy (Stein and Langfitt 1974) and rarely in asymptomatic individuals (Kieffer et al. 1973). Investigations in patients and in experimental animals led to the conclusion, that ventricular stasis does not occur during the early development of hydrocephalus but is an end state phenomenon (James et al. 1973). Ventricular stasis is at least partially correlated with the absolute size of the ventricles but this may not be the only factor (Bartelt et al. 1975, Han 1979). Symon and Hinzpeter (1977) found responders to shunting in cases with mixed patterns. Vivenza et al. (1980) found that 6 out of 18 cases of NPH that improved after shunting did not show ventricular filling on the isotope scan.

Black (1980) investigated 33 patients with idiopathic NPH. Of the 11 patients with a typical pattern on the isotope cisternogram 8 (73%) improved; however, of the 13 patients with a mixed pattern 4 (31%) improved and of the 9 patients with a normal scan 5 (55%) improved. It appears therefore that the isotope cisternography is not a completely reliable guide in selecting patients with NPH for surgery.

8.3.2 Isotope transfer

Using the technique described by Chou and French in 1955, Behrman et al. (1971) measured the rate of appearance of radioactivity in the blood following intrathecal injection of RISA. Two types of curves were obtained. Normal curves showed a rapid rise of activity followed by a high plateau and were seen in patients with normal CSF dynamics. Those showing a lower rise and no tendency to plateau were regarded as abnormal and were seen in patients with ventricular stasis.

Belloni et al. (1976) found no relationship between surgical results in patients with NPH and absolute levels of activity, but the ratio between the 48 and 24 hours samples was higher in 8 out of 9 patients who responded to shunting than in the remainders.

Stein and Langfitt (1974) measured the half clearance value of RISA in 43 patients, the average being 2.8 days in both good and bad results, compared with the normal of 1.8 days.

Mahaley et al. (1974) compared the isotope transfer in patients with NPH and Alzheimer's disease, finding that those with NPH tended to have lower blood levels.

8.4 Computerized tomography (CT scanning)

The introduction of the non-traumatic CT has replaced PEG as the most important technique for assessment of ventricular size and visualization of the cerebral convolutions and sulci. An advantage of CT over PEG is that visualization of the sulci on CT does not depend on filling the sulci with air, thus sparing the patient the morbidity associated with the introduction of air. However, there are problems, particularly with reference to quantification of cerebral atrophy (Roberts et al. 1976). The pattern and extent of ventricular enlargement is clearly shown on CT together with gross widening of the cerebral sulci and fissures. Any space-occupying lesions such as tumours are readily visible. The postoperative CT scan is helpful both in determining an anatomic response to shunting and in detecting complications such as subdural haematoma or ventricular collapse. It also provides useful information regarding the position of the catheter in relation to the ventricular contour.

Gado et al. (1976) compared radionuclide cisternography and CT scanning in 44 patients and found a good correlation between the two tests. Patients with the cisternographic pattern of NPH tended to show more severe degrees of lateral ventricular dilatation with involvement of the third and fourth ventricles and relative sparing of the cerebral sulci, but those who had a cisternographic pattern consistent with cerebral atrophy showed less ventricular and more sulcal dilatation. However, the demonstration of normal sulci was not helpful in differentiating NPH from atrophy. The presence of fourth ventricular dilatation correlated most strongly with NPH. The study of Le May and Hochberg (1979) also provides an aid for distinguishing between NPH and hydrocephalus ex vacuo by means of CT. In NPH they found a more severe degree of lateral ventricular dilatation and visualization of both temporal horn tips, while the Sylvian and interhemispheric fissures and cerebral sulci were not visible. The introduction of CT has tremendously advanced the evaluation of cerebral atrophy in the demented patient. However, a single CT examination can be misleading and serial studies may be required for a precise diagnosis of atrophy. Two cases of "pseudo-atrophy" described by Dublin and Dublin (1978) will illustrate the problems in the evaluation of "atrophic" change on the basis of one CT examination alone. One case of "pseudo-atrophy" was caused by malnutrition, the other by communicating hydrocephalus.

Dublin and Dublin described a 75-year-old man who underwent a shunting for dementia, after a CT scan showed hydrocephalic dilatation of the ventricles with suggested associated cortical atrophy. After shunting the patient showed

moderate improvement and the CT scan demonstrated a decrease in ventricular size as well as a decrease in size of the cortical sulci. The patient eventually succumbed to pneumomia. At post-mortem a supernumerary dural membrane was found beneath the main portion of the dura mater, covering the cerebral vertex. Microscopic examination showed that arachnoidal villi were encased within the membrane. No significant evidence of cortical atrophy was found. Reversible atrophy is also described in patients with anorexia nervosa (Enzmann and Lane 1977) and in Cushing's disease (Heinz et al. 1977).

Although in NPH specific patterns are seen on CT, it is impossible to identify specific CT indications for shunting.

Gunasekera and Richardson (1977) found that a dilated fourth ventricle is not a satisfactory prognostic indication for surgery. Laws and Mokri (1977) believed that atrophy is not a significant predictor for poor response.

Wiggli et al. (1976) found a close correlation between the results of CT scanning and radioisotope cisternography. However, when put to the definitive test of the response to shunting the results are most disappointing.

Jacobs et al. (1978) found in 47 patients with NPH who had undergone surgery that the ventricles remained enlarged in 33% of the improved and in 29% of the failure group. There was no relationship between the findings of enlarged postoperative ventricles or cortical atrophy and the clinical responses to surgery. Periventricular areas of decreased densities having characteristics of white matter oedema were discerned in 20 of the 59 patients (34%). The periventricular decreased densities were observed to develop during the evolution of NPH and to disappear following ventricular shunting. It is believed that this phenomenon is due to transependymal resorption of CSF and is indicative of an active hydrocephalic process.

Mori et al. (1977) found that it was not visible in long-standing chronic compensated hydrocephalus. However, it is not specific, as this has been detected in other conditions (Sjaastad et al. 1969).

None of the 27 NPH cases in the study of Tans (1979) showed cortical atrophy at the convexity, but 4 demonstrated a prominent dilatation of the Sylvian and interhemispheric fissures, initially interpreted as atrophy. Tans proposed that it seems more plausible, however, to attribute this dilatation to obstruction of CSF flow in the high frontoparietal region. In Tans' study the most consistent CT finding of NPH was dilatation of the temporal horns. He concludes that NPH is highly unlikely if the temporal horn tips are not visualized on CT.

Børgesen and Gjerris (1982) found in their study of 80 patients with NPH

that the size of the ventricles bears no relation to the outcome of shunting. Periventricular hypodensity was found in 16 patients, all of whom had effect from the shunt. The periventricular hypodensity had disappeared in all 16 patients following CT. Of 33 patients with cortical sulci larger than 5.0 mm, 15 had effect from shunting.

Two findings in CT were significantly correlated with improvement after shunting; periventricular hypodensity and small cortical sulci. Both findings were present in 16 patients, all of whom improved after shunting.

In 6 patients, who all had effect from the shunt, the ventricular system was unchanged 3 months after operation. In 7 patients who did not improve the ventricular system returned to normal. The same result was found in 19 shunted patients by Shenkin et al. (1975). This indicates that the ventricular dilatation is not the sole factor responsible for the clinical symptoms.

Petersen et al. (1985) could not document any clear relationships between ventricular size, amount of cortical atrophy, periventricular lucency and clinical improvement after shunting in 29 NPH patients. The presence of periventricular lucency before and after shunting did not correlate with a positive response.

8.5 Metrizamide CT cisternography

The study of CSF dynamics using CT and intrathecal metrizamide was introduced by Greitz and Hindmarsh (1974). Later Drayer et al. (1977) studied hydrocephalic patients after the injection of 6-7 ml of metrizamide into the lumbar subarachnoid space. After 30 seconds in the Trendelenburg position, cranial CT scans were performed immediately at 6, 12 and 24 hours. The examination is comparable to radioisotope cisternography and supplies information regarding the morphology of the CSF spaces and dynamics simultaneously. In normal individuals scans at 12 and 24 hours show metrizamide in the cerebral and cerebellar substance contiguous with the subarachnoid space. This "blush" is most distinct in the cerebellum, lateral cerebral convexity and parasagittal area.

Drayer et al. (1977) also described the pattern in hydrocephalus. There is ventricular stasis at 24 hours and occasionally at 48 hours, asymmetrical filling of the Sylvian fissures, a diminished parasagittal blush and periventricular oedema highlighted between metrizamide in the lateral ventricle and the normal cerebral white matter. The "diffuse" pattern was seen in diffuse degenerative abnormalities such as Alzheimer's disease. This disease showed

ventricular stasis at 6 and 12 hours but not at 24 hours. Periventricular oedema was not seen and the parasagittal blush was normal.

Hindmarsh and Greitz (1977) compared radionuclide cisternography with metrizamide CT cisternography in 51 patients and found no single symptom, sign or combination of signs to be able to distinguish between atrophy and NPH.

In summary, metrizamide CT cisternography can demonstrate the same CSF dynamics shown previously by radioisotope cisternography. Why this method should prove any more reliable in predicting the response to a shunt than isotope cisternography is not clear. It is expensive in terms of precious CT scanning time.

8.6 Electroencephalography

Most articles on NPH either do not mention or only briefly mention the EEG findings. The 3 patients first reported by Adams et al. (1965) had abnormal EEGs with diffuse theta or delta waves. In their review of 29 patients (Ojemann et al. 1969) there was only a general statement about the EEG, indicating that it was usually abnormal, showing non-specific changes with random slow waves in the theta or delta range. They did not divide their EEGs between patients with known and unknown causes of NPH.

Brown and Goldensohn (1973) reported the EEG findings in 11 cases with idiopathic NPH. Six patients had normal records and 5 had abnormalities, varying from focal to diffuse theta and delta activity. One patient showed rare monorhythmic frontal delta activity. The experience of Greenberg et al. (1977) in the 67 patients who had EEG was quite different: only 6 out of 67 (8.9%) EEGs were normal. A variety of non-specific abnormalities (focal, diffuse and bilateral) was seen. Interestingly enough, even 6 out of 18 patients with no background alpha rhythm improved. Jacobs et al. (1976) described in 21 out of 25 patients with idiopathic NPH generalized slowing. Laws and Mokri (1977) reported the EEG findings in 43 patients. The findings varied from entirely normal studies in 3 patients, through various grades of generalized dysrhythmias, to severely abnormal studies with focal findings. The presence of a "projected" dysrhythmia was of little value in making the diagnosis or predicting the outcome of surgery. Postoperative electroencephalograms frequently showed changes attributable to the shunt procedures, but rarely showed improvement even in patients whose symptoms were dramatic-

ally relieved. This is in contrast to the findings of Magnaes (1978) who described the correlation between EEG and clinical result of shunting in 45 patients. Clinical improvement after shunting is correlated with more normalized EEGs, as is seen in Table IV.

Also Petersen et al. (1985) found in the 30 patients with idiopathic NPH who underwent EEG, various results, from normal to several types of dysrhythmias. Two out of 3 patients with a "projected" rhythm responded favourably to shunting.

Kamphuisen (1980) reported 1 patient with NPH who had EEG registration during lumbar puncture. The patient improved clinically during LP, and the EEG showed disappearance of slow activities.

There is agreement that the EEG is not helpful in selecting patients with NPH for surgery (Guidetti and Gagliardi 1972, Wood et al. 1974, Stein and Langfitt 1974).

8.7 Spinal infusion test

In 1970 Katzman and Hussey developed the intrathecal lumbar spinal infusion test, which is used to evaluate the efficiency of the CSF absorption system. So it tests functions. The amount of CSF that can be absorbed by a healthy subject may be 4 to 8 times the quantity produced. This means that in healthy subjects changes in volume can be absorbed without any increase in pressure, thanks to the absorption capacity of the system. This homeostatic capacity is possibly lost in NPH as a result of the reduced absorption activity, so that when the system is forced with a constant intrathecal saline or artificial CSF infusion rate of 0.76 ml/min (twice the normal CSF production) equilibrium is reached at a pressure higher than normal (Katzman and Hussey 1970, Hussey et al. 1970). The test is considered abnormal if the CSF pressure exceeds 300 mmH_2O during the 60 minutes infusion.

Lorenzo et al. (1974) studied CSF absorption in 5 patients with NPH using ventriculo-cisternal perfusion. The 5 patients showed 3 different abnormal patterns of CSF absorption.

In type I, absorption occurred at a normal rate, but the pressure at which CSF absorption appeared to begin was increased from 68 mm to 164 mmH_2O, and the equilibrium pressure (the pressure at which CSF formation equals absorption) was increased from 112 to 208 mmH_2O.

In type II, absorption increased linearly with pressure, as expected, but

at a much slower rate.

In type III, absorption increased with pressure at an apparently normal rate at low pressure levels. But when pressures of 120 to 160 mmH_2O were reached, the rate of absorption was dramatically reduced.

The three types of absorption defects and the normal pattern are illustrated in Fig. III. The pathological changes that underlie each type of absorption defect are not clear. Whether a defect in arachnoid villus function, rather than obliteration of the subarachnoid spaces, is associated with a specific type of absorption defect is not known.

Katzman's infusion test has been modified several times. However, the correlation of abnormal infusion test with improvement following shunt surgery has not been high (Wolinsky et al. 1973, Stein and Langfitt 1974, Stevenaert et al. 1976, Belloni et al. 1976).

Hartmann and Alberti (1977) could not distinguish normal patients from NPH patients by means of the spinal infusion test using the infusion test rate of 0.76 ml/min. However, when the infusion rate was doubled (1.47 ml/min), CSF pressure increased faster in hydrocephalic patients than in control patients.

Tans (1979) found that CT and the spinal infusion test taken together correctly distinguished atrophy from NPH in 71% of his patients.

Børgesen et al. (1978) developed a lumboventricular perfusion test and measured the conductance to outflow of CSF (C_{out}). The method is based on a constant infusion rate at different, controlled, constant intracranial pressure levels. Ringer lactate is infused via a lumbar cannula at a rate of 1.5 to 4.5 ml/min. The pressure level is controlled by the height of the outflow tip of the catheter from the ventricles. The unabsorbed fluid flows out through the catheter from the ventricles and is measured gravimetrically in two periods of 5 minutes at 3 to 5 different pressure levels. The volume of absorbed fluid (V_{abs}) is calculated from

$$V_{abs} = V_{inf} + V_{CSF} - V_{out}$$

a formula in which V_{inf} is infusion rate, V_{CSF} is CSF production rate (0.4 ml/min) and V_{out} is volume of outflowing fluid. V_{abs} is plotted against pressure. The slope of the resulting regression curve is

$$\frac{d\ V_{abs}}{d\ P}\ \text{ml/min/mmHg}$$

and expresses the conductance to outflow of CSF = C_{out}

In the study of Børgesen and Gjerris (1982), 51 patients had a C_{out} below 0.08 and 49 of them improved after shunting, while none of the 13

patients with C_{out} above 0.08 (ml/min/mmHg) improved after shunting. Disadvantages of this test are the risk of infection and the fact that it is not easy to perform; it gives the patient discomfort (headache, nausea); it is opposite to the therapeutic measure to decrease CSF pressure.

8.8 Continuous intracranial pressure (ICP) monitoring

A saline-filled catheter inserted into the lateral ventricle or subdural space, but also in the epidural space, normally records a pulsatile pressure of 0-10 mmHg depending on the foramen of Monro when the patient is lying flat.

Thanks to Guillaume and Janny (1951) and Lundberg (1960) intracranial pressure can be measured continuously. Display on a recorder reveals a rapid oscillation corresponding to arterial pulsation, but also a slower wave form synchronous with respiration and produced by changes in intrathoracic pressure (Lundberg 1960). Coughing or sneezing provokes transient rises in ICP of the order of 100 mmHg. Not only does the mean ICP rise but also spontaneous periodic waves appear in states of raised ICP.

Lundberg (1960) described 3 types of pressure waves - A, B and C - in his patients with raised ICP. Only the A-waves he found to be of clinical significance.

A-waves were characterized as large plateau-like formations recurring at intervals of varying length with an amplitude of 50-100 mmHg and a duration of 5-20 minutes. There was a causal relationship between the A-waves and intermittent neurological symptoms and attacks occurring in intracranial hypertension.

Plateau waves were associated with the development of hydrocephalic attacks (Ingvar and Lundberg 1961).

Lundberg (1960) had drawn attention to the ability of patients to terminate a pressure wave by voluntary hyperventilation.

Hulme and Cooper (1966) noted their increased incidence during sleep, Risberg et al. (1969) found an accompanying decrease in CBF.

B-waves were defined as rhythmic oscillations occurring more or less regularly at a frequency of ½-2 per minute and with an amplitude to 50 mmHg. They have been observed to occur during periodic respiration at the onset of sleep in patients with normal ICP (Briggs 1973). They were not thought to be of pathological significance until Crocard (1976) suggested that they might

influence the progression of ventricular dilatation in NPH.

C-waves were defined as rhythmic oscillations of a relatively small amplitude and a frequency of 4-8 per minute with an amplitude to 20 mmHg. Judging from their frequency, the C-waves are related to rhythmic variation of the systemic arterial pressure called Traube-Hering Mayer's waves.

Measurement of intraventricular pressure through a ventricular catheter is a well-known method and has the advantage of being a direct method. The greatest disadvantage is the risk of infection but catheter blockages and leakage of fluid occur as well. These problems can be avoided by making use of epidural methods, with the dura mater remaining closed and the transducer applied against it. Local dura condition seems to be the most important factor contributing to the errors of epidural pressure measurement. In general, good correlation between epidural and ventricular pressures is reported (Ikeyama et al. 1977, Gjerris et al. 1980, Koster and Kuypers 1980).

The paradox in NPH arose from isolated measurement of CSF pressure when performing lumbar puncture when it was said to be normal. However, continuous recording of ICP had revealed spontaneous periods of waves of raised pressure (Symon et al. 1972).

Symon et al. (1972) made continuous overnight measurement of extradural pressure for 24 to 48 hours in 18 patients suspected of having NPH. They found that these patients had mean pressures of 4 to 20 mmHg (54 to 272 mm H_2O) although all had normal pressures on lumbar puncture measurement. Two patterns of pressure were described.

Nine patients with maximum pressures ranging from 13 to 33 mmHg (176 to 448 mmH_2O) had flat and featureless traces. The other nine with maximum pressures of 23 to 51 mmHg (312 to 693 mmH_2O) had more active traces containing B-waves and generally unstable recordings. Some of these patients also developed spontaneoous waves similar to the A-plateau-waves of Lundberg, but they were of shorter duration. The authors suggested that the term NPH should be altered into "episodically raised pressure hydrocephalus". An explanation for these episodes might be that, in a critically balanced equilibrium between production and resorption of CSF, transient changes in intracranial blood volume during sleep, for example, might disturb the equilibrium of the intracranial pressure and result in a wave of increased pressure. Equilibrium could be restored to normal either by hyperventilation or by some adaptation of intracranial blood volume as is believed to occur in the fading of the more typical Lundberg A-waves in very high intracranial pressure states.

After shunt surgery these pressure waves disappeared (Symon et al. 1972).

Nornes et al. (1973) found no difference in pressure traces between patients with NPH and control subjects. In both groups nocturnal pressure was higher than during the day and pressure transients were observed.

Chawla et al. (1974) studied 12 patients with NPH. Seven patients with flat, featureless low pressure traces did not respond to shunting, the 5 who showed intermittent B- and plateau-waves all showed some improvement following surgery.

Sjaastad and Nornes (1976) described 5 patients with NPH (4 of them responded to shunting) and continuously raised ICP (>25 cmH_2O) without clinical signs of increased pressure.

The findings of Symon and Dorsch (1975) in a larger group of over 30 patients with NPH indicated that the yield of improvement in these cases is by no means 100%. The improvement rate ran into some 66% of patients who showed some abnormality of the pressure profile.

Rather more hopeful results were reported by Belloni et al. (1976). They analysed the value of the mean ventricular pressure and the amplitude of the corresponding pulse pressure recorded during relaxed wakefulness, as well as their variations during nocturnal physiological sleep, and following jugular vein compression. They concluded that the ratio between mean ventricular pressure and this pulse pressure was the most reliable for surgical prognosis. They noted that this ratio ranged from 1.7 to 5.5 (mean 2.7) in those patients who improved following surgery and from 1.1 to 1.7 (mean 1.4) in the patients who did not improve. There was a clear separation between these 2 groups of 14 cases. They did not base their criteria for shunting on the presence or absence of unusual wave patterns during sleep.

Crockard et al. (1976) studied 19 patients and found that pressure traces showing B-waves of more than 10 mmHg and present during more than 10% of the monitoring time would be evidence of CSF pathway obstruction and they thought that such patients might benefit from a shunt.

Martin (1978) however, described B-waves in an apparently normal brain.

Brock (1977) described spontaneously periodic increases of ventricular fluid pressure in 8 out of 9 patients with NPH. These waves, which look like B-pressure-waves, differ from B-waves as to their forms and Brock prefers to name them ramp waves. After shunting these ramp waves had vanished.

Unfortunately, the origin of B-waves is still not clearly understood. They may be accompanied by changes in breathing pattern and some, but not all, disappear with controlled ventilation. B-waves, like plateau-waves, may reflect periodic changes in cerebral blood volume provoked by an ill-defined

central periodicity (Risberg et al. 1969). To add to the confusion very brief periods of B-waves may be present in some normal people, possibly related to periods of REM sleep (Martin 1978, Gücer and Vierstein 1979).

Børgesen et al. (1979) studied 40 patients with NPH by monitoring intraventricular pressure during a 24-hour-period. The results from this study showed that intraventricular pressure measurements are of little help in the selection of patients with NPH who may be expected to improve after shunting therapy.

Pickard et al. (1980) studied 23 patients with NPH. Intraventricular pressure was recorded continuously for 24-48 hours and analysed in respect of baseline ICP and occurrence of B-waves (1 per minute waves). The baseline ICP differed in the two groups; responders 12.5 ±6 mmHg and non-responders 7.5 ±2 mmHg. Patients who did not respond to shunting had a mean ICP of below 15 mmHg.

In conclusion, the continuous ICP monitoring is not consistently helpful (Adams 1980).

8.9 Test removal of CSF

Fisher (1978) and Wikkelsø et al. (1982) have suggested that test removal of CSF, if followed by transient clinical improvement, should be a good indication that the patient will improve after a shunt. However, the improvement with a shunt is often delayed so that Fisher's test is only useful if positive. One cannot exclude a disturbance in CSF dynamics and hydrocephalic dementia when no improvement is reached (Adams 1980).

8.10 CSF analysis

Usually cell count and protein content are normal in idiopathic NPH (Laws and Mokri 1977).

Glasner and Piepgras (1978) found in communicating hydrocephalus typical protein alteration in the electrophoresis of CSF. In the case of a pathological CSF circulation an increase of the absolute values of alpha$_1$ globulins was discovered. The alpha$_1$ globulins are equal to or higher than the prealbumins. Percentage values show high alpha$_1$ globulins and low albumins.

albumin : 11.2 ±3.1 ---- normal CSF circulation

alpha$_1$ globulin : 8.0 ±3.2 ---- pathological circulation

The CSF lactate levels and lactate/pyruvate ratios in ventricular CSF have been studied by Raisis et al. (1975) in patients with communicating hydrocephalus, before and after shunting. When responsible for diminished cerebral perfusion, hydrocephalus causes sufficient cerebral ischaemia to increase lactate production and to elevate the L/P ratio. Raisis found a decrease in L/P ratio in 64% of the hydrocephalic patients after shunting. So, the L/P ratio in ventricular CSF could be of assistence in the evaluation of patients with hydrocephalus.

Andersson and Roos (1966, 1969) found that CSF concentrations of 5-HIAA were altered in hydrocephalic children and suggested a possible diagnostic value for such a determination. A decreased lumbar CSF concentration of HVA was observed by Edvinsson et al. (1972) in hydrocephalic rabbits.

Maira et al. (1975) have described decreased values of HVA in lumbar CSF in all 13 patients with NPH. The HVA lumbar concentration remained after shunt procedure. The ventricular CSF concentration of HVA was normal before surgery; in 2 cases it became higher after surgery. No important variations were found in the lumbar and ventricular CSF concentrations of 5-HIAA. Maira made the following hypothesis: HVA enters the CSF mainly via the lateral ventricles. The inversion of the direction of CSF flow and the vicarious absorption in the lateral ventricles would reduce the diffusion of the dopamine metabolite to lower CSF spaces. This might account for the low HVA concentration in lumbar CSF. The hypothesis seems supported by the low HVA concentrations in the lumbar CSF in all patients successfully treated with a CSF shunt. The shunt, draining fluid from the lateral ventricles, in fact induces or further favours the inversion of CSF flow.

There are no apparent correlations between altered CSF dynamics and CSF concentration of 5-HIAA at lumbar level. This may depend on the ubiquitous release of the metabolite in the CNS - that is, at cerebral as well as at spinal level.

An alternative explanation for the findings obtained is that the concentration of amine metabolites in the CSF is dependent not so much - or not only - on CSF dynamics but rather on the metabolism of amines at cerebral level.

On this basis, the finding of normal concentration of HVA in the ventricles associated with low concentration at lumbar levels in patients with

reduced absorption of CSF might indicate a decreased production of the dopamine acid metabolite. The dopaminergic systems might, in fact, be involved in the structural damage of the periventricular structures, as shown experimentally (Edvinsson et al. 1972). The occurrence of signs of Parkinsonism in some normotensive hydrocephalics would favour such a possibility. On the other hand, the increase of HVA ventricular concentration observed in some patients after shunting might indicate a normalization of the previously damaged dopamine cerebral systems.

8.11 Neuropsychological testing

Since dementia is not a disease, but a syndrome that can be produced by a large variety of aetiologies, it is logical that in the dementias different patterns of neuropsychologic impairment are found.

Psychological testing should serve as an aid in clinical evaluation, not primarily as a diagnostic instrument.

Neuropsychological evaluation may be helfpul in the differential diagnosis of the dementias and as evaluative procedure for the patient with identified dementia. Psychometric testing, when tolerated by the patient, may be extremely helpful in documenting congnitive impairment, evaluation of the mental status with emphasis on the presence of disorientation, loss of memory, deteriorating, intellectual ability and mood lability. The intelligence test most widely used is the Wechsler Adult Intelligence Scale (WAIS), which has proved especially useful in the assessment of dementia. The Wechsler Memory Scale assesses both general and discrete brain function. It tests various aspects of memory including orientation in person, time, place and current events, mental control items such as counting backwards, reciting the alphabet etc. etc. Tests of visuomotor performance include Bender Gestalt test and Benton Visual Retention test.

Several investigations conducted in recent years, however, indicated the difficulties in differentiating the psychologic features characteristic of the different forms of dementia, since similar patterns of intellectual impairment have been found in Alzheimer's disease, multi-infarct dementia, NPH etc.

Yet a few authors (Vivenza et al. 1980, Gustafson and Hagberg 1978, Gainotti et al. 1980) described some characteristic psychologic features in NPH. The early course of this illness may be characterized by symptoms of

apathy, lack of spontaneity or initiative with irregular outbursts of irritability and poverty of thought, which wrongly suggest a depressive illness. There is impairment of both recent and remote memory and disorientation. In early stages frank confabulation may occur. Other cognitive functions are normal or have minor impairment. No aphasial apraxias or agnosias are seen as is the case in the "cortical dementias". The dementia of NPH has features as seen in the "subcortical dementias". This refers to a syndrome found in patients in which prominent pathological changes are seen in subcortical structures (Albert et al. 1974, Albert 1978, Neumann and Cohn 1967). The symptom complex of subcortical dementia is similar to the behavioural syndrome seen in patients with frontal lobe damage. This is not surprising because according to Nauta (1971) "the unique feature of the neural circuitry of the frontal lobes is the reciprocal relationship of the frontal cortex with the limbic system and its subcortical correspondents". The dementia in NPH is also mentioned as an apathetic-amnestic dementia.

Gustafson and Hagberg (1978) investigated 23 patients with hydrocephalic dementia of heterogeneous aetiology and 17 patients with Alzheimer's disease. Before operation the NPH patients showed inertia, emotional unconcern, disorientation and amnesia for recent events, which symptoms are similar to those found in the cases of Alzheimer's disease. Confabulation was more frequently observed in the group with NPH, while amnesia for remote events, apraxia, expressive aphasia, anxiousness and restlessness were more common in the Alzheimer's disease group. Confabulation, gait disturbance, urinary incontinence and emotional unconcern were more prominent before operation in patients who improved after shunting. On the other hand, apraxia, expressive aphasia and dysarthria were somewhat more frequent in cases that did not improve after shunting. Psychometric testing in NPH patients showed a general cognitive reduction with reference to the main dysfunction within the spatio-perceptual performance (constructional apraxia). The findings are similar to what has been observed in patients with uraemia (Hagberg 1974) and hepatic cirrhosis (Victor et al. 1976). This might indicate a more diffuse cerebral dysfunction in NPH in contrast to the accentuated temporo-parieto-occipital cortical degeneration in Alzheimer's disease (Brun and Gustafson 1976). Postoperative improvement was found in 50% of the NPH group. The improvement was most evident in patients with a better spatio-perceptual performance.

It might be justified to assume that the specific symptoms are more directly related to the hydrocephalus and that the less consistent symptoms might be related to other factors, such as concomitant injuries to different

brain structures (Granholm and Svendgaard 1972), the aetiology of the hydrocephalus or the patients' premorbid personality.

Gainotti et al. (1980) found that patients with Alzheimer's disease perform consistently worse on most verbal and visuospatial tasks, than patients with NPH. They also suggested that since memory impairment does not clearly differentiate dementia properly from depression it is necessary to combine memory tests with other intelligence and visuo-constrictive tests to distinguish the onset of dementia from depression.

Vivenza et al. (1980) found in 18 patients with NPH that the psychic picture consists of disturbance of temporospatial memory disorientation. Suitable for surgical treatment are those with mental deterioration in which temporospatial disorientation predominates and the preservation of a potential intellectual capacity is observed.

9. SHUNTING AND RESULTS OF SURGICAL TREATMENT

9.1 Shunting

Treatment of NPH depends on diverting the flow of CSF from the ventricles to an alternate location for absorption and is, since 1965, a commonly accepted and recommended form of treatment.

However, Bachman (1977) presented a 72-year-old man with NPH, including dementia, incontinence and apraxic gait, who did not receive a shunt and, nevertheless, showed spontaneous improvement in his mental function over the next 2½ years.

Hughes et al. (1978) evaluated the natural history of 12 idiopathic NPH patients who had not had surgery and the results in 27 surgical idiopathic NPH patients. When the numbers of those improved were compared with a combination of those who were stable or worse, there was a significant difference between surgical and non-surgical patients ($p < 0.01$) in favour of the surgical group. Fifty percent of the 12 patients who had not been operated on were stable for up to 36 months and 50% showed progression.

This comparison emphasizes the equally varied course that patients can experience without a shunt.

Shunt procedures

Two types of shunt procedures are commonly used: the ventriculoatrial and the ventriculoperitoneal.

In ventriculoatrial shunting a proximal catheter is, under general anaesthesia, inserted into the right lateral ventricle via a parieto-temporo-occipital burr hole and connected to a distal catheter that is inserted via the internal jugular vein into the right atrium. In ventriculoperitoneal shunting the proximal catheter is the same one as that in the ventriculoatrial shunt but the distal catheter is passed subcutaneously to the abdomen and inserted into the peritoneum via a right subcostal incision.

Which type of shunt?

Opinions differ as to the best type of shunt to be used in NPH: a low or medium valve; ventriculoatrial or ventriculoperitoneal shunts.

There are no controlled trials in adult hydrocephalus - only anecdotal observations.

With the exception of three ventriculopleural shunts, Laws and Mokri (1977) found no significant correlation between successful clinical response or incidence of shunt-related complications and the route of shunting (atrial or peritoneal) or the specific type of apparatus used in their group of 53 patients with NPH. In these patients the lateral ventricle was cannulated via a parieto-occipital burr hole in each case, nearly always on the right side.

To avoid infection and blockage, the shunt system should be as simple as possible (Raimondi et al. 1977).

Some neurosurgeons prefer the ventriculoatrial shunt because it has proved effective over long periods of time with a very low incidence of complications.

In obese patients it is easier to insert a ventriculoatrial shunt than a ventriculoperitoneal shunt.

Many subdural haematomas are present within the first postoperative day. Hence, care should be taken not to decompress the ventricles too quickly, and the patient should be kept flat in bed for 2-3 days.

When subjects stand, intracranial pressure becomes negative relative to the heart. An antisiphon device that shuts off in case of such negative pres-

sure gradients has been developed. Unfortunately, in practice such antisiphon systems do not always avert the formation of a subdural haematoma (Hughes et al. 1978).

9.2 Results of surgical treatment

The percentage of patients who benefit from neurosurgical shunt procedures varies considerably from series to series (Table V). Since the entity of NPH is not well defined, the results depend - to a large extent - on the group of patients selected for operation.

The relatively small size of the individual series together with the variety and complexity of tests involved and the methods of assessing improvement prevents adequate statistical analysis of the results.

Katzman (1977) gathered 351 adult NPH patients from the literature; 144 were idiopathic and 207 were secondary NPH patients. The overall incidence of positive responders after shunting was 55.5%, the percentage in the secondary NPH group was 64.7%, whereas in the idiopathic group only 40.9% improved. Messert and Wannamaker (1974) found improvement after surgery in 51% of the 142 cases from the literature.

The history of a cause of the NPH tends to give a better result than in the idiopathic NPH. Stein and Langfitt (1974) found improvement in 8 out of 10 patients subjected to operation for the secondary NPH. Of the idiopathic cases only one fourth benefited from treatment.

Udvarhelyi et al. (1975) observed improvement in 60% of shunted idiopathic NPH patients and drew attention to the high incidence of complications (44%) and postoperative death (9%).

In retrospective studies comprising a total of 157 patients Salmon (1972), Udvarhelyi et al. (1975) and Belloni et al. (1976) all failed to find a totally satisfactory method of selecting patients for surgery.

Laws and Mokri (1977), Fisher (1977), Black (1980) and Adams (1980) stressed the importance of clinical features in relation to the outcome of surgery. Laws and Mokri (1977) found some improvement in 74% of 19 patients with the clinical triad gait disturbance, dementia and urinary incontinence. Black (1980) reported 19 positive responders out of a group of 31 patients with this clinical triad (67.2%), while only 31.6% of the patients with dementia and gait disturbance alone improved. Of 62 patients given shunts for idiopathic NPH, 46.8% showed improvement of which 27.4% showed virtually complete

recovery.

Guidetti and Gagliardi (1980) reported on 58 patients with the clinical and laboratory diagnosis of NPH; 58.6% showed marked improvement and 13.8% moderate improvement after surgery; 27.6% did not benefit at all. In the 35 patients with secondary NPH the rate of success was 80%, in the 23 patients with idiopathic NPH the results were less favourable (61%).

In agreement with Fisher (1977) Guidetti and Gagliardi (1980) found that the results were better in patients whose first symptoms were gait disturbances followed by mental and sphincter disturbances. This clinical sequence permitted correct diagnosis and therapy in 65.8% of the cases. Among 25 patients whose duration of symptoms was less than 6 months 18 patients improved following shunting. On the other hand, 15 of the 30 patients, whose symptoms were present over six months showed postoperative improvement (Udvarhelyi et al. 1975).

Hughes et al. (1978) found in 33% of 37 adult patients with idiopathic NPH definite improvement after surgery. No diagnostic procedures, including clinical signs, accurately predicted the outcome of surgery. Hughes et al. (1978) also gathered 307 patients with idiopathic NPH who were older than 40 years of age, published between 1965-1977. Of 307 patients, who were all treated with shunting, 144 (47%) appeared to have improved by more than a minimal amount.

Using the spinal infusion test and intracranial pressure monitoring Janny et al. (1981) found in 56 patients who underwent a medium pressure Holter ventriculoatrial shunting an improvement of 47%.

Pickard et al. (1980) found in 26 patients with the same criteria improvement in 61.5%.

Petersen et al. (1985) observed in 42% of 45 patients with idiopathic NPH continuous improvement, Børgesen and Gjerris (1982) in 67.7% of 31 patients with idiopathic NPH; of the total group of 64 patients 76.6% improved.

The review of results of NPH treatment, irrespective of what criteria were used in selection of patients, does not indicate uniform improvement in any series.

It may be that we look in vain for a treatment which will reverse the symptoms of a clinical condition dependent not only on the disordered pathophysiology of CSF circulation, but also on the collateral ageing process, which such patients demonstrate. It is also possible that prolonged hydrocephalus reaches an irreversible stage (McCullough et al. 1970).

9.3. The predictive value of clinical features with respect to improvement in clinical status after shunting

9.3.1 Length of history

Belloni et al. (1976) did not notice any relation between the presumed duration of the clinical symptomatology and the surgical results in 22 patients. It has to be stressed, however, that the gradual onset of the syndrome makes it difficult to define its onset precisely, particularly when the first sign is slight mental deterioration which can easily escape recognition.

Børgesen and Gjerris (1982) found that 16 out of 33 patients with a history longer than two years had an effect from the shunt. The tendency towards effect with a shorter history was not statistically significant.

Petersen et al. (1985) found the mean duration from the onset of symptoms to operation in 45 idiopathic NPH patients was 25 months for those who improved and 37.4 months for those who did not.

9.3.2 Age of the patient

Age showed no correlation with the effect from shunting (Børgesen and Gjerris 1982). Greenberg et al. (1977) also found that patients over 70 years of age did improve as well as younger patients, as is demonstrated in the next list.

43 patients $\leq$70 years : 37.2% improved
21 patients 71-75 years: 38% improved
7 patients 76-80 years: 29% improved
1 patient >80 years : 1 improved

9.3.3 Presence of the "classical triad"

No single clinical finding can predict the outcome of shunting to a degree of more than 66%, as is the case with severe gait disturbances (Børgesen and Gjerris 1982). In the study of Børgesen and Gjerris (1982), 51 out of 80 patients had the combination of dementia, gait disturbances and urinary incontinence; 33 out of 51 patients (66%) had an effect of the drain. In the study of Petersen et al. (1985), 25 out of 45 patients had the classical triad and 20 out of 25 patients (80%) improved. In this study gait distur-

bance was most likely to improve (74%); dementia was least likely to improve (57%) and urinary incontinence next most likely to improve (65%).

Among clinical factors, the age of the patient, degree of deficit and duration of disability were all irrelevant to shunt outcome in the study of Black (1980) in 62 patients with idiopathic NPH. The presence of the "classical triad" was the best clinical "guarantee" of satisfactory outcome; of 31 patients with this constellation a total of 61.2% improved; of 19 patients without urinary incontinence 31.6% improved.

9.3.4 Shunt testing and follow-up

Follow-up of patients makes a heavy demand on hospital facilities and must be limited to what appears necessary.

Clinical improvement was always apparent within 3 months after shunting (Magnaes 1978) and also Borgesen and Gjerris (1982) have shown that changes one year after operation are the same as when seen at 3 months follow-up. Magnaes (1978) suggests the following procedure in follow-up.

1. Before discharge, shunt function should be tested and failing shunts revised and tested again.
2. After three months shunts should be tested.

Unimproved patients with well-functioning drains must be regarded as therapeutic failures.

Patients with failing shunts should have their shunts revised and tested, and should be readmitted after three months.

Shunt testing can be done by injection of the radioisotope Technetium 99 (1 millicurie) in the drain with follow-up of its disappearance curve and controlling the CSF pressure in the ventricular drain.

Control CT can give information as to whether ventricular size has changed or not.

10. COMPLICATIONS OF SHUNT SURGERY

Udvarhelyi et al. (1975) reported in 55 shunted patients a complication rate of 44% of which 9% was fatal. Greenberg et al. (1977) found a surgical mortality rate of 6.9% in 73 patients (died within 1 month after surgery). The operative deaths are primarily effects of anaesthesia in this elderly and

sometimes fragile population. Pituitary function may be depressed in some of these patients and should be corrected preoperatively (Barber and Garvan 1978). The major complication is shunt malfunction.

Illingworth et al. (1971) found in 43 patients with ventriculocaval shunts 71 complications; the commonest of these was blockage of the ventricular catheter. Of the 71 complications, 45 occurred within 3 months after the initial insertion and only 6 out of 66 patients surviving at that time developed complications later than 1 year after the initial insertion.

Many authors reported compliction rates, infection rate and subdural collection rate (Table VI). Subdural collection can be symptomatic or asymptomatic. Subdural haematomas can usually be treated by shunt ligation, but remain an important source of morbidity (McCullough and Fox 1974, Samuelson et al. 1972).

Samuelson et al. (1972) reported a higher incidence of subdural haematomas (20.8%) complicating shunt surgery in patients with NPH than in patients with hypertensive hydrocephalus (5%).

The incidence of shunt infections has been reported to be 0-18% (Table VI) and was found to be higher among patients with ventriculoatrial shunts than in patients with ventriculoperitoneal shunts (Little et al. 1972). Udvarhelyi et al. (1975) found most of these infections were of staphylococcal origin, responding to antibiotics with or without shunt removal.

Some cases with candida meningitis have been reported in patients with CSF shunts in place (Surgerman and Massanari 1980). Cure was obtained only after removal of the shunt tubes.

Ventriculitis and septicaemia have been recognized as complications of ventriculocaval shunts since 1959.

Other hazards of indwelling shunt systems include: blockage of the catheters and Holtervalves, disconnection, superior vena cava obstruction, pulmonary emboli, wound dehiscence and infection (Table VII). The intrusion of tissue from choroid plexus into the ventricular catheter is a common cause of obstruction (Hakim 1969) and is less likely to occur if the catheter tip is in the anterior horn.

A form of malfunction which may be difficult to manage is that associated with slit-ventricles and overdrainage phenomena (transient low pressure headaches).

The ventricles may collapse and obstruct the ventricular catheter. Six out of 56 patients in the study of Laws and Mokri (1977) developed seizures after shunting.

Transient neurological disturbance such as diplopia, tremor or aphasia may be related either to shunt catheter placement or to sudden changes in CSF dynamics.

Table I. Classification of hydrocephalus

I Non-communicating hydrocephalus: elevated pressure
- obstruction to flow within the ventricular system
- colloid cyst of IIIrd ventricle
- aqueductal stenosis
- cerebellar tumour obstructing IVth ventricle
- obstruction at the exit foramina of the IVth ventricle
- Dandy-Walker syndrome
- Arnold Chiari malformation
II Communicating hydrocephalus
- non-obstructive (hydrocephalus ex vacuo)
- obstructive
- high pressure
- **normal pressure hydrocephalus**

Table II. Aetiology of NPH as reported by Katzman (1977) in 914 adult patients

Subarachnoid haemorrhage		315
Head injury		102
Aqueductal stenosis		34
Meningitis		34
Post-craniotomy		43
Basilar artery ectasia or aneurysm		11
Basilar impression with or without Paget's disease		4
Syringomyelia		1
Other aetiology		56
Idiopathic or unknown		314
associated with:		
- Parkinson's disease	15	
- Alzheimer's disease	7	
- Cerebrovascular disease	4	

Table III. Review of clinical features in NPH syndrome

1. **Gait disturbance**	- spasticity with increased reflexes in legs and bilateral Babinski's signs - unsteadiness at tandem walking - spastic ataxia (frontal) - gait apraxia
2. **Dementia**	- mild and insidious in onset - decrease in spontaneity - memory impairment - disorientation - confabulations - reduced performal intelligence
3. **Incontinence**	- urinary (anosognosia of micturition) - faecal
4. **Parkinsonian signs**	- movement disorders (gait) - bradykinesia, masked facies - rigidity/tremor
5. **Psychiatric symptoms**	- apathy/inertia - depression - agitation - anxiety - hallucinations - paranoia
6. **Disturbance of consciousness**	
7. **Additional findings**	- Hoffmann's-, grasp- and snout reflexes - nystagmus - disturbance of extraocular motility - headache - falling spells - trigeminal sensory symptoms - disturbance in sugar metabolism

Table IV. EEG and result of shunting

EEG	SHUNTING			
	improved patients		non-improved patients	
	before	after	before	after
generalized dysrhythmia	17	6	18	17
focal changes	1	1	2	2
normal	4	15	3	4

Table V. Review of results of NPH treatment

		CRITERIA	CASES	IMPROVEMENT
Ojemann	1969	PEG/RIHSA/Neurology	28	65% idiopathic
Benson	1970	PEG/RIHSA	14	64%
McCullough	1970	RIHSA	18	39%
Bannister	1972	RIHSA	8	0% idiopathic
Salmon	1972	PEG/RIHSA/Neurology	80	26% idiopathic (40% all)
Shenkin	1973	PEG/Neurology	28	64% idiopathic
Stein	1974	No prediction possible	33	24% idiopathic
Rau	1974	RIHSA/PEG	12	8.3% idiopathic
Wood	1974	RIHSA/PEG/Neurology	55	60%
Messert	1974	Review literature	142	51%
Udvarhelyi	1975	RIHSA/Neurology	55	60% idiopathic
Belloni	1976	PEG/ICP/RIHSA	22	63%
Jacobs	1976	Neurology	20	72%
Fisher	1977	Neurology	30	53%
Greenberg	1977	PEG/RIHSA	73	37% idiopathic
Laws	1977	Neurology	19	74%
Katzman	1977	Review literature	351 (144)	55.5% 40.9% idiopathic
Hughes	1978	No prediction possible Review literature	37 307	33% idiopathic 47% idiopathic
Gustavson	1978	PEG/RIHSA/Neurology	23	50%
Guidetti	1980	PEG/RIHSA	58 (23)	72.4% 61% idiopathic
Black	1980	PEG/RIHSA/Neurology/CT	62	46.8% idiopathic
Vivenza	1980	Psychol. invest./CT	18	66%
Pickard	1980	CT/ICP monitoring/Infusion test	26	61.5%
Janny	1981	Inf. test/ICP monitoring/ Cisternography/Neurology	56	47%
Børgesen	1982	Lumbar perfusion test/CT/ Neurology	64 (31)	76% 67.7% idiopathic
Petersen	1985	Neurology	45	42% idiopathic

Table VI. Review of complications of shunt surgery in NPH

	NUMBER OF CASES	TOTAL COMPLICATION RATE	SURGICAL MORTALITY RATE	SUBDURAL HAEMATOMA	INFECTION RATE	SEIZURES	SHUNT MALFUNCTION	
Samuelson 1972	--			20.8%				
McCullough 1974	--			23%				
Udvarhelyi 1975	55	44%	9%	4%	18%	5.5%	10.9%	
Laws 1977	56	38%	0%	14%	3.6%	10.7%	37.5%	
Greenberg 1977	73	39.7%	6.9%	2.7%	5.6%	1.4%	--	*
Hughes 1978	37	51.4%	--	16.2%	--	2.7%	8.1%	
Black 1980	62	35.4%	4.8%	11.3%	--	6.4%	11.3%	
Pickard 1980	26	46%	--	3.9%	3.9%	--	27%	
Janny 1981	56	--	5.4%	9%	0%	--	3%	
Børgesen 1982	64	22%	3.1%	6.3%	6.3%	--	6.3%	
Petersen 1985	45	31%	0%	15.5%	4.4%	6.7%	20%	

*2.8%: intracranial hypotensive headaches

Table VII. Complications of shunts

1. Overdrainage phenomena, ventricular collapse
2. Symptomatic subdural haematoma
3. Asymptomatic subdural haematoma
4. Extradural haematoma
5. Intracerebral haematoma
6. Shunt infection, local wound infection
7. Meningitis
8. Ventriculitis
9. Septicaemia
10. Skin erosions over the shunt, wound dehiscence
11. Obstruction, disconnection of the catheter
12. Subcutaneous accumulation of CSF
13. Seizures
14. Superior vena cava obstruction
15. Pulmonary emboli
16. Non-haemorrhagic stroke
17. Transient neurological disturbances (diplopia, tremor)

Chapter III

PATHOPHYSIOLOGY OF NORMAL PRESSURE HYDROCEPHALUS

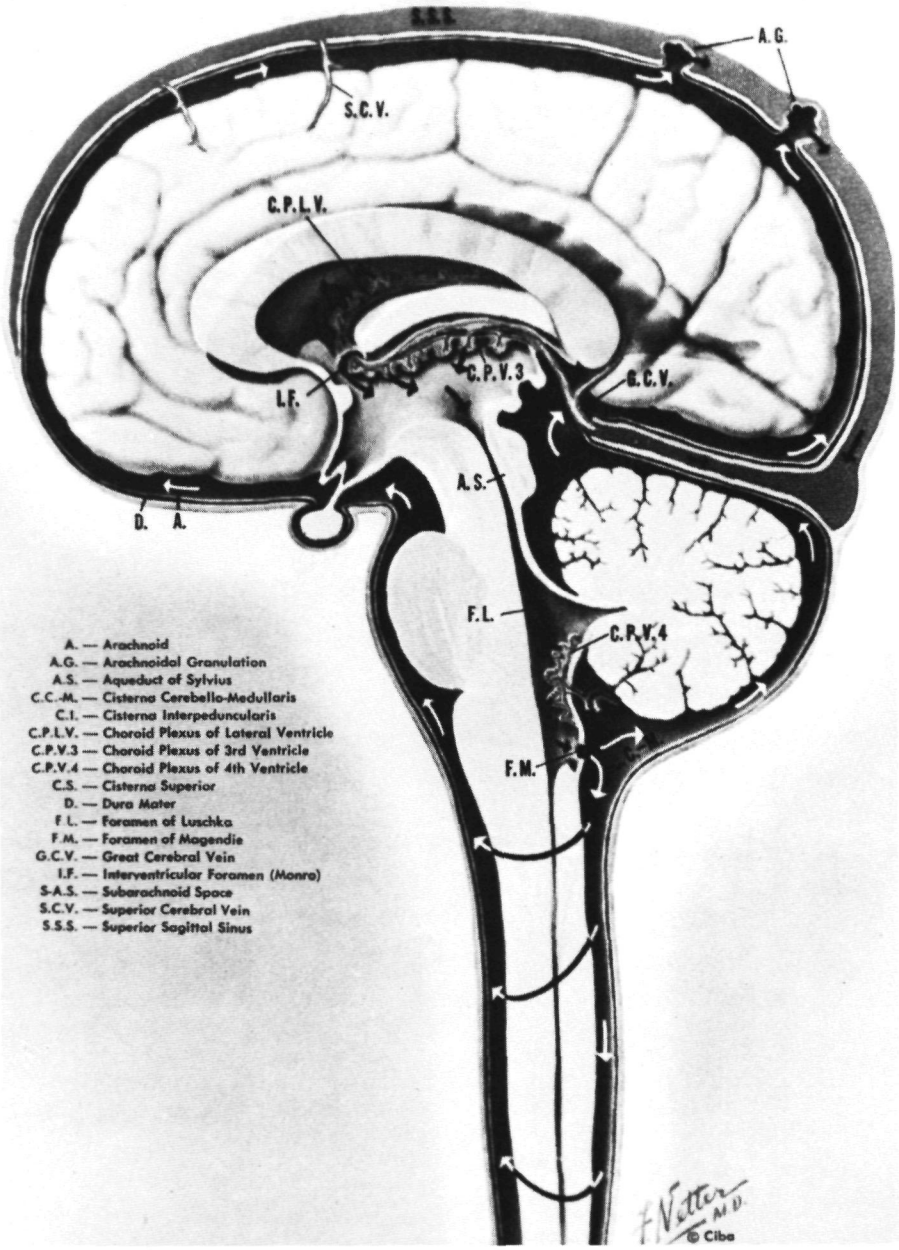
S.S.S.
A.G.
S.C.V.
C.P.L.V.
C.P.V.3
G.C.V.
I.F.
A.S.
D.
A.
F.L.
C.P.V.4
F.M.
A. — Arachnoid
A.G. — Arachnoidal Granulation
A.S. — Aqueduct of Sylvius
C.C.-M. — Cisterna Cerebello-Medullaris
C.I. — Cisterna Interpeduncularis
C.P.L.V. — Choroid Plexus of Lateral Ventricle
C.P.V.3 — Choroid Plexus of 3rd Ventricle
C.P.V.4 — Choroid Plexus of 4th Ventricle
C.S. — Cisterna Superior
D. — Dura Mater
F.L. — Foramen of Luschka
F.M. — Foramen of Magendie
G.C.V. — Great Cerebral Vein
I.F. — Interventricular Foramen (Monro)
S.A.S. — Subarachnoid Space
S.C.V. — Superior Cerebral Vein
S.S.S. — Superior Sagittal Sinus
F. Netter M.D.
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Fig. IV

1. CIRCULATION OF THE CEREBROSPINAL FLUID (CSF)

In the adult human, CSF is secreted at a rate of 0.3 to 0.4 ml/min. or about 500 ml per 24 hours (Davson 1967, Cutler et al. 1968, Lorenzo et al. 1970) so that the total volume of CSF (150 ml) is replaced every 8 hours.

1.1 Production of CSF

The choroid plexus is the principal source of CSF and secretes about 70% of the total CSF production. The remaining 30% is probably derived from the brain's capillary bed and from metabolic waterproduction (Bering and Sato 1963, Pollay and Curl 1967). Evidence for secretion of CSF in the spinal region has been examined by Hammerstad et al. (1969) and Lorenzo et al. (1970). An important point is that the formation of CSF is relatively independent of the pressure within the ventricles and subarachnoid space, although the rate of formation does decrease at very high pressures (Welch 1975). The rate of formation is also probably relatively independent of the systemic blood pressure (Welch and Sadler 1966). About 25% of the blood flowing into the choroid plexuses is secreted as CSF. In view of this large extraction the choroidal blood flow may place an upper limit on the ependymal secretory rate (Welch and Sadler 1966).

CSF formation can be reduced by drugs that inhibit sodium and potassium activated adenosine triphosphatase or carbonic anhydrase (Davson and Luck 1957). No clear-cut evidence exists that agents such as acetazolamide, furosemide, corticosteroids or cardiac glycosides are of value in reducing CSF formation (Cutler and Spertell 1982).

1.2 Bulk flow of CSF

Extensive data concerning the migration of dyes, radioisotopes and other tracers injected into the CSF have now firmly established that CSF flows in bulk from sites of origin to sites of absorption (Fig. IV).

The fluid formed in the lateral ventricles passes out through the paired foramina of Monro to reach the third ventricle and via the aqueduct of Sylvius it flows into the fourth ventricle. A small quantity of fluid reaches the fourth ventricle through the central canal of the spinal cord. From the

fourth ventricle the CSF escapes through one of three exits; through the paired lateral foramina of Luschka, which direct fluid around the brainstem into the cerebello-pontine angle and prepontine cisterns, and through the midline foramen of Magendie, entering into the cisterna magna. From the cisterna magna, CSF then flows in several directions: superiorly into the subarachnoid space investing the cerebellar hemispheres; caudally into the spinal subarachnoid space; and cephaladly into the premedullary, prepontine and cerebello-pontine angle cisterns. From the basilar cisterns, the bulk fow of CSF sweeps upwards along two major routes: A) a ventral route through the interpeduncular and prechiasmatic cisterns from which it passes, mainly through the Sylvian fissure and callosal cisterns, to the subarachnoid space investing the lateral and frontal aspects of the cerebral hemispheres, and B) along a dorsomedial route through the ambient cisterns and cisterna venae magnae cerebri, from which CSF passes to the subarachnoid space investing the medial and posterior aspects of the cerebral hemispheres. Here via the arachnoid villi the fluid is emptied into the great venous dural sinuses, particularly the superior sagittal sinus.

In the spinal subarachnoid space, the bulk flow of CSF appears to follow a downward route behind the cord, posterior to the dentate ligaments to the lumbar theca and upward in front of the cord to the basilar cisterns (Di Chiro 1966, Milhorat 1972).

Although the mechanisms for propelling CSF along its circulatory route are not altogether understood, the following factors are involved (Milhorat 1975):

1) the continuous outpouring of newly formed CSF,
2) ventricular ependymal ciliary activity,
3) ventricular pulsations meaning the combined effects of respiratory variations and the pulsations from choroid plexuses and cerebral arteries, which are situated in the larger cisternae,
4) the pressure gradient across the arachnoid villi (Shulman et al. 1964),
5) "suction pump" action of the dural sinuses (Bradley 1970). This action, which depends on the high velocity of the central blood flow through the fixed diameter of the sinuses and the low intraluminal pressure that develops at the circumference of the sinus wall where the arachnoid villi enter, may explain how the circulation of CSF continues through a wide range of postural pressures.

The membranous coverings of the brain, the meninges, are, from without inwards, the dura, the arachnoid and the pia. Between the dura mater and the pia mater is a delicate layer of reticular fibres forming a weblike non-vascular membrane, the arachnoid. This membrane also extends along the roots of the cranial and spinal nerves. The space between the arachnoid and the pia mater is filled with CSF and is calles subarachnoid space.

As classically described (Weed 1914) the arachnoid membrane is a delicate layer of connective tissue covered both internally and externally by a layer of cuboidal mesothelium. Fine trabeculae are produced off, which bridge the gap between arachnoid and pia, forming a sponge-like meshwork through which the enclosed CSF may percolate. Electronmicroscopic observations have shown the arachnoid membrane is made up of cuboidal cells. These cells have a very watery cytoplasma and are contained in long irregular pseudopods which fit together and interdigitate with those of adjacent cells. They form what appears to be a protoplastic layer which may be several cells thick (Nelson et al. 1961). However, there is no regularity in the structure so that at given points the CSF cisterns penetrate deeply into the layer and may even reach the surface, i.e. the dural mesothelium. Hence it is incorrect to speak of the arachnoid as a complete epithelial barrier.

In regions adjacent to the superior sagittal sinus the cerebral pia-arachnoid causes tufted prolongations which protrude through the meningeal layer of the dura into the superior sagittal sinus. The structures that are visible to the naked eye, are the so-called arachnoid granulations of Pacchioni (1721), which are found only in the adult. These granulations are variable in number and location and each consists of numerous arachnoid villi. These villi have a thin outer limiting membrane beneath which there are bundles of collagenous and elastic fibres. Cells similar to those of the pia-arachnoid lie scattered among the fibres, and small oval epithelial cells cap the surface of the villi. In man the arachnoid villi occur predominantly in the so-called lacunae laterales.

According to Clark (1920) they are in fact developments of the anastomic connections of the meningeal and diploic veins with the dural sinuses. Initially, the surface mesothelial lining of the arachnoid villus is continuous with that of the arachnoid mater from which it is derived but may later fuse with the mesothelial lining of the venous sinus or lacuna. The walls of the blood vessels into which the arachnoid villi project are supported by the

dura and are, therefore, unlikely to collapse when the pressure of the CSF is greater than that in the blood vessels.

How the villi are distributed, has been summarized by Millen and Woollam (1962). In order of frequency the commonest sites are the superior sagittal sinus, the transverse sinus and the cavernous sinus.

From the moment that the early experiments on human corpses by Key and Retzius (1875) were reported, the sites and mechanisms of CSF absorption have been the subjects of intensive study. It is now clear that a major route along which CSF returns to the blood is one via the arachnoid villi.

The rate of absorption of bulk flow is equal to the rate of bulk formation i.e. about 0.35 ml/min. (Cutler et al. 1968). The mechanism of fluid absorption is dependent on the difference in hydrostatic pressures between the intracranial venous system and the CSF (Welch and Friedman 1960) and on the resistance of arachnoid villi to CSF flow. These concepts are largely based on Weed's (1935) early experiments including the distribution of Prussian blue following intrathecal injection. Welch and Friedman (1960) have shown that the arachnoid villi act as functional valves that allow a one-way flow of CSF into the venous system. In man, Cutler et al. (1968) found a linear relationship between the rate of absorption of CSF and intraventricular pressure between 68 and 250 mmH_2O; higher pressures were not studied, however. CSF absorption ceased at pressures below 68 mmH_2O and it was suggested that this pressure may approximate that in the superior sagittal sinus. Thus the opening pressure of these "valves" has been estimated to be about 68 mmH_2O in man (Cutler et al. 1968). Fig. III summarizes these data in graphic form.

Summarizing, the following functions of the arachnoid villi have been made:

a) CSF flow across the villi is in a one-way direction.

b) CSF absorption is a passive, pressure dependent process with a critical opening pressure.

c) Particulate matter can pass from CSF to blood and not in reverse direction (Welch and Friedman 1960).

d) Flow decreases as protein content in CSF increases (Davson et al. 1970, 1973).

e) The rate at which the constituents of the CSF leave to enter the blood is virtually independent of the molecular weight of the substance if it is highly water-soluble.

It must be concluded that the drainage route must be through a tissue containing pores at least as large as the diameter of a serum albumin molecule

and of erythrocytes. Adams and Prawirohardjo (1959), Dupont et al. (1961), Bradford et al. (1962) and Usai (1968) showed that injected cells passed the arachnoid villi in fractions varying from 0.5% to 25%.

The drainage of CSF into the blood is unaffected by changing the colloid osmotic pressure of the CSF (Davson et al. 1970, 1973).

Electronmicroscopic studies of the arachnoid villi have shown that the cells of the mesothelial covering of the villus are sealed together by typical tight junctions. However, this finding is not in accordance with the known function of the villus in passing unrestrictedly substances with molecular weights such as the serum albumin molecule.

The answer to this problem was given by Tripathi and Tripathi (1974) in a new concept concerning the basic facts of resorption.

Similar to the findings in the endothelial lining of Schlemm's canal in the eye, they also identified large vacuoles, formed by invagination into the body of the mesothelial cells, covering the arachnoid villi in monkeys.

Serial sections of the villus revealed a continuous pathway between the CSF and the blood in the dural sinus in the form of temporary transmesothelial channels. The mesothelial cells lining the arachnoid villus undergo a series of changes, beginning with a small invagination into the substance of the cell and resulting in a complete cleavage of the cell to permit the flow of fluid through it; later the process can be reversed. The cycle involved in this process is presented in Fig. V.

There was some evidence that the rate of vacuolization increased when CSF pressure increased. This should provide a mechanism for compensating for increased intracranial pressure.

Accessory routes of CSF absorption include the ventricular ependyma, the leptomeninges and the lymphatics of spinal and cranial nerves (Milhorat 1972, Bowsher 1960). There is little doubt that CSF can be absorbed from the spinal subarachnoid space by spinal arachnoid granulations penetrating the epidural veins in association with spinal nerve roots (Welch and Pollay 1963).

Recent studies by Bradbury and Cole (1980) have demonstrated that a significant fraction of CSF enters the general circulation via the lymph ducts of he head. Such a lymphatic pathway had been demonstrated earlier by Courtice and Simmonds (1951) who cannulated the lymph ducts and found that plasma proteins and erythrocytes injected into the ventricles appeared in the lymph. The losses described by Bradbury and Cole (1980) were flowing into the main lymphatic trunks draining the head, and the significant pathway was along the olfactory tracts and into the lymphatics of the nose. This "subsidiary path-

way" may well be of importance when the main pathway is occluded as happens in communicating hydrocephalus in which the lesion is in the arachnoid villi. In normal circumstances the importance of the accessory routes of absorption is not known, but they assume greater importance when the normal route of drainage is disturbed.

1.4 Functions of the third circulation

One of the functions of the CSF is a mechanical protective one. It helps support the weight of the brain and it acts as a buffer between the brain and the adjacent dura and skull. The 1,400 gm. brain weighs about 50 gm. when weighed in water and thus the CSF is giving buoyancy to the brain and spinal cord. By virtue of its buoyant effect, the CSF substantially reduces the momentum (inertia) of the brain in response to other acceleratory forces besided gravitation. In this way the feebly rigid brain can withstand stresses inflicted on the head in the course of everyday life and is the spinal cord protected from compression during bending of the spinal column. Not only by virtue of its CSF bath is the brain protected form damaging ballottement within the cranium, but continuing simultaneous shifts in the rates of formation and absorption of the fluid ensure hydraulic homeostasis.

The CSF also contributes to the maintenance of relatively constant pressure-volume relationships within the cranial cavity (Davson 1967, Langfitt 1969). An increase in brain volume is balanced by a reduced volume of the CSF and vice versa according to the Monro-Kellie doctrine. In 1783, Alexander Monro had deduced that the cranium was a rigid box filled with a "nearly incompressible" brain and that therefore the quantity of blood within the head must be the same at all times, whether in health or disease. Monro's concepts were confirmed by the experimental work of George Kellie (1824) and resulted in the "Monro-Kellie hypothesis" which postulated that the volume of blood within the brain did not change (Fishman 1980).

Burrows (1846) later modified this concept by adding that the blood volume of the brain could change, but only reciprocally with the volumes of brain and CSF within the cranial cavity. Studies of intracranial pressure-volume relationships and cerebrovascular autoregulation still allude to the Monro-Kellie hypothesis.

Besides, the displacement of the CSF from the skull causes a further displacement of blood. The whole system acts as a hydraulic brake.

The lymphatic-like role of the CSF already suggested by Cushing (1926) and Flexner (1933) is recovered nowadays. Many components are found in much lower concentrations in CSF than in plasma, an observation that led Davson (1963) to the concept of a "sinkaction" of the CSF. This is especially of importance for lipid-insoluble substances (Cserr 1971). Cserr (1971) has emphasized a most clinically apparent function of CSF: that of an excretory fluid that retrieves and removes products of cerebral metabolism out of the central nervous system. For this lymphatic-like function a dynamic and circulating medium is necessary.

The chemical composition of the CSF is maintained within narrow limits despite major changes in the composition of plasma and in view of its equilibration with the extracellular fluid of the nervous tissue, the CSF contributes to the maintenance of a stable chemical environment for the central nervous system.

In conclusion, the CSF long regarded as little more than a watery cushion for the brain and spinal cord is a dynamic and circulating medium whose fluidity and biological functions justify its description as "the third circulation".

2. PATHOPHYSIOLOGY OF NPH

Although a disproportion between production and absorption of CSF has been accepted as an important factor, the precise mechanisms behind the development of NPH are uncertain. It is difficult to explain how the ventricles come to be so greatly enlarged when the pressure within them is normal and how a reduction of pressure by as little as 20-30 mmH_2O can permit restoration of nervous function and also partially relieve the ventricular distension.

Several theories have been put forward. In their classical works of 1965 on NPH, Hakim and Adams suggested that the increase in ventricular size was initially due to an increase in intraventricular pressure.

The CSF pressure, defined as that pressure which must be exerted to prevent any outflow of CSF through a needle inserted in the subarachnoid space or ventricle (Davson 1956), represents the force per unit area of ventricular or subarachnoid space. The effective expansile force on the ventricular wall is the ventricular pressure times ventricular area (Pascal's law).

Thus, if the force is constant, an increase in ventricular volume should be accompanied by a proportional decrease in pressure. The principle of in-

creasing force in the ventricle as the area of its expansion might be called the "hydraulic press effect" of Hakim and Adams (1965). It may also explain the sites of greatest enlargement (differential expansion) of the ventricular system, the force being greater in the largest part such as the anterior horns of the lateral ventricles. It also accounts for the progression of neurological symptoms during the time that the pressure is normal. A given pressure exerts a greater force in a large ventricular system than in a normal one. A pressure of 170 or 180 mmH_2O in enlarged ventricles may produce symptoms, whereas it would not do so in a normal-sized ventricular system. The same normal pressure can maintain the ventricles in enlarged state (new steady state).

Geschwind (1968), however, dismissed this "total force" hypothesis on mathematical grounds. Geschwind (1968) objected that the ventricular wall is not a tissue of uniform consistency at all points and must change at different degrees of expansion. He suggests that in some cases there may have been intermittent peaks of high pressure without elevation of the mean pressure. Such pulsatile forces could lead to rapid loss of proteins and liquids from the surrounding white matter, altering its ability to withstand the pressure normally exerted upon it. There is no doubt that the status of the ventricular wall and its supporting tissue is a factor in determining ventricular size and shape. A paraventricular lesion, which alters the quality of the wall, will allow outpouching of the ventricular wall and diverticulation. This happens at normal CSF pressures, but is even more pronounced with hydrocephalus. Geschwind (1968) also suggests there must be a pressure gradient from ventricle to subarachnoid space for continued enlargement of the ventricles. Meadows (1973) also gives a possible explanation for NPH based on the pressure gradient between ventricle and cortical subarachnoid space.

One possibility is that once the subarachnoid space is compressed or obliterated over the convexities of the cerebral hemispheres, the cerebral mantle becomes subjected to greater strain for a given stress. In keeping with this concept, Hoff and Barber (1974) found that a transcerebral mantle pressure between the ventricle and the subdural space did exist in NPH. Using constant infusion manometry, they monitored ventricular and subdural pressure simultaneously. In patients with NPH they showed a pressure gradient between the ventricle and the subdural space which increased as the ventricular pressure increased. In patients without ventricular dilation, no gradient was measured across the cerebral mantle. Hoff and Barber (1974) concluded this supported the theory of Fishman (1966) which stated that ventricular pressure

exceeding cortical surface pressure may simulate an intraventricular water hammer, which in turn eventually produces dilated ventricles.

Geschwind (1968) gives another answer to the problem of the differential expansion of the ventricular system, which was pointed out by Adams (1966) and Hakim and Adams (1965).

Adams (1966) reported a case in which a patient developed a progressive dementing syndrome associated with the steady enlargement of a cyst communicating with one ventricle in the face of a ventricular enlargement. This syndrome was reversed by shunting.

Geschwind (1968) suggests that it seems most likely that the patient was suffering from NPH, however the cyst wall, being weaker than the ventricular walls, underwent expansion while ventricular size changed only slightly. Geschwind's theory is not in conflict with the results of the classical studies of Bering (1962) who stressed the importance of the pulsatile forces transmitted from the choroid plexus as important factors in ventricular enlargement. Even the effect of these peaks of pressure depends on the structural properties of the wall.

More recently, Hakim et al. (1976) viewed the brain as a viscoelastic sponge. The cells of the sponge are the venous capillaries and extracellular spaces and the liquids and proteins within white matter. The compressibility of the sponge is controlled by shifts of fluid into the venous system which then controls the general pressure level within the cells of the sponge. The effective CSF pressure which squeezes liquid out of the parenchymal sponge is the gradient between the intraventricular CSF pressure and the venous blood pressure. Changes in ventricular size are triggered by the effective CSF pressure and not by the ICP measured in relation to atmospheric pressure. Hakim et al. (1976) stated that very high ventricular pressure could be compatible with normal or even small ventricular size, and large ventricles could develop with slightly increased ICP.

Jensen (1979) showed on the basis of Pascal and Laplace that the ventricular dilatation in acquired hydrocephalus is due to a primary increase in the intraventricular pressure and that a new steady state can be reached irrespective of whether the intraventricular pressure is increased or normal. The increase of pressure is due to a disproportion between the production and reabsorption of CSF. A new steady state occurs when the amounts of CSF formed and absorbed are in equilibrium.

Experimental studies suggest the CSF pressure returns to normal as a consequence of the development of alternative routes of CSF absorption.

Following obstruction of CSF pathways, alternate routes of absorption must be quickly developed. The rate of formation of CSF is such that if no CSF were absorbed the volume of the ventricular and subarachnoid spaces would increase four- to sixfold in one day, a situation which inevitably leads to death.

However, the formation of CSF from the choroid plexuses is also reduced in high ventricular pressure and it is possible that the choroid plexuses can reabsorb CSF (Sahar 1972). Alternative routes of absorption in hydrocephalus can be illustrated in experimental animals and in patients.

Using dyes and radioactive tracers, it can be shown that there is transependymal absorption (Heinz et al. 1970, Milhorat et al. 1970, Strecker et al. 1973, 1974, Hammock et al. 1974), increased absorption through the vessels of the pia-arachnoid (Sweet 1971, Sweet et al. 1974) and absorption in the spinal canals (Di Chiro et al. 1976, Sweet 1972) along the spinal roots (Pollay 1972).

If the capacity is increased by transependymal absorption, damage to the brain will occur.

By means of isotope ventriculography Milhorat and Hammock (1971) demonstrated a distinct double contour around the ventricular walls in hydrocephalic patients. He stated that this visualizes a penetration of labelled albumin into the subependymal tissue and is evidence of transependymal absorption. The accumulation of albumin and the presence of CSF in the subependymal part of the white matter causes damage to brain tissue. Electronmicroscopic studies show that as hydrocephalus develops the ependyma becomes stretched and flattened. There is gross extracellular oedema and destruction of fibres and cellular elements. As the process continues, the white matter becomes atrophic and spongy. This damage alters the quality of the wall and allows progressive enlargement of the ventricles in case of normal pressure (Ojemann 1971). The condition for a new steady state is increase in the tensile strength of the ventricular wall. This is attained through gliosis in the subependymal part of the white matter. These changes have been observed in several animal experiments (Milhorat et al. 1970, Strecker et al. 1973, Rubin et al. 1976, Koto et al. 1977) and in a patient (Jensen 1979). The microscopic changes in the ventricular wall described by Jensen (1979) showed destruction of the ependyma and vacuoles in the juxta ventricular part of the white matter surrounded by gliosis.

A disproportion between the production and absorption of CSF has been accepted to be the primary aetiological factor in NPH.

Adams (1975) suggests that in idiopathic NPH a prior low grade asymptomatical meningeal disease, possibly inflammation of undetermined aetiology, has occurred. More simply, the atrophic changes consequent upon ageing may have diminished the tensile strength in the cerebral tissues surrounding the ventricles, thus allowing ventricular enlargement by the pulsations from the choroid plexus. This in turn would displace the cortex towards the calvarium and compress the subarachnoid space so that resorption of CSF is disturbed and a vicious circle is reached.

White et al. (1979) described this compensatory mechanism; it is the centrifugal motion of a thin layer of the outer portion of the hemispheres into the cortical subarachnoid space with deplacement of the CSF contained in this space, downwards to the basal cisterns. That this mechanism plays a part in compensating for cerebral volume increases has been suggested by Guinane (1977). He found that drainage of the CSF from the cortical subarachnoid space of rabbits caused hydrocephalus and that the cellular damage was found not in the cortex but around the walls of the ventricles. Guinane (1977) postulated that this localization was due to maximal stress and strain at the brain-CSF interfaces as a result of the pulsatile forces within the skull. He further showed that if the CSF was drained from the cortical surface of only one hemisphere, the resulting hydrocephalus was confined to the ipsilateral ventricle.

White et al. (1979) suggest that the failure of the aqueduct to vent sufficient CSF during systole results in a disproportionate increase in the pulsatile pressure of the CSF in the lateral and third ventricles during systole and that, as a result, increased stress is placed upon the tissues in the region of the brain-CSF interface. White et al. (1979) think the benefit resulting from shunting is due not to the draining of CSF but to the formation of an additional venting pathway that reduces excessive increases of intraventricular pulsatile pressure.

It is relevant that Gardner (1965) has postulated a similar mechanism for the formation of a syringomyelia or hydromelia. Such cases are often associated with a deformity of the hindbrain resulting in obstruction to the pulsatile outflow of CSF from the fourth ventricle into the spinal subarachnoid space. Such an obstruction could be responsible, if the hypothesis of White et al. (1979) is accepted, for the hydrocephalus with which such cases are often associated.

Earnest et al. (1974) presented two patients with multiple cerebral lacunae and some diffuse white matter changes due to hydrocephalus; one of them

responded to ventricular shunting. He wondered if the vascular damage could reduce tissue bulk and tensile strength, allowing the ventricles to enlarge under the stress of the increased intraventricular CSF pulse pressure due to hypertensive vascular disease.

At autopsy there has been found a high incidence of hypertensive cerebrovascular disease in patients who had been diagnosed in life as suffering from NPH.

Also Van Crevel (1972) suggests a relationship between blood and CSF circulation in the pathogenesis of NPH. The idea that the brain may act as a pump during systole is supported by DuBoulay et al. (1972). The pulse is known to arise from the arteries of the brain (Dunbar et al. 1966). With arterial systole there is a flow of 10 cc of blood into the cranial cavity and a flow of 10 cc of CSF into the spinal region. With arterial diastole the flow is reversed. Van Crevel calls this phenomenon the external "hydraulic press effect" of the brain. External because this CSF is coming from the basilar cisterns, as there is a compression of the third ventricle during arterial systole (DuBoulay et al. 1972). As there is a block in the basilar cisterns in NPH he suggests a disturbance in the external hydraulic press action, so that the brain gets a stroke with every heart-beat which causes brain damage.

A combination of several factors (external hydraulic press effect, diminished CSF resorption) causes internal hydrocephalus and reduced CBF may be responsible for the clinical symptoms (Van Crevel 1972). A steady state can be attained by a greater internal hydraulic press effect because the dilatation of the third ventricle allows CSF to flow during the systole from the ventricles into the lower regions.

Greitz (1969) postulated that the circulatory disturbance might be responsible for serious but reversible symptoms. CBF has been shown to be reduced in NPH to an extent which correlates with the degree of ventricular dilation, and improvement in CBF follows shunting procedures (Greitz 1969, Raichle et al. 1974, Mathew et al. 1975).

The decreased cerebral blood flow may be the direct result of compression of capillaries and veins or the consequence of changes in vasomotor centres.

CBF is normally independent of changes in arterial or CSF pressures and is controlled by the metabolic need of the brain.

Granholm and Lofgren (1975) suggested that NPH patients would have little compensatory reserve with which to accommodate changes in CBF, and small increases in PCO_2 would produce large increases in intracranial pressure

and a widening of the CSF pulse pressure. These are the changes thought to produce the progression of symptoms and the ventricular enlargement (Lorenzo et al. 1970, Chawla et al. 1974, Belloni et al. 1976).

Certain support for a critical unbalance between production and resorption of CSF is supplied by the work of Lorenzo et al. (1970) and Hussey et al. (1970) who used spinal infusion tests.

Because of the investigation with continuous intracranial pressure monitoring in NPH patients, Symon et al. (1972) suggested that the so-called NPH might be more appropriately termed "episodically raised pressure hydrocephalus".

An explanation for these episodes of increased pressure might be that in a critically balanced equilibrium between production and resorption of CSF transient changes in intracranial blood volume during sleep, for example, might disturb the equilibrium of the intracranial pressure and result in a wave of increased pressure. Equilibrium could be restored to normal either by hyperventilation or by some adaptation of intracranial blood-volume.

In conclusion, there have been considerable speculations about the pathophysiology of NPH. Referring to these speculations we tend to agree with Di Rocco et al. (1977) who concluded there were two pathogenetic mechanisms in NPH which may operate independently or together, either simultaneously or in sequence. The first is defective CSF circulation or absorption with subsequent (initial) increase in intraventricular CSF pressure. The second factor is changing tensile properties of periventricular white matter due to oedema, spongiosis, ependymal disruption or parenchymal damage due to vascular insufficiency (Koto et al. 1977), ageing diseases or other degenerative diseases. A summary is given in Table VIII.

However, the viscoelastic properties of the cerebrum are complex. The metabolic basis of hydrostatic pressure-induced atrophy of the periventricular white matter is hard to understand. The biological basis for ventricular enlargement and its return towards normal after shunting remains largely unexplained. Perhaps a key factor is the degree of transependymal movement of CSF which induces the pressure atrophy of the periventricular white matter. This suggested mechanism needs further study with regard to the effect of transcerebral pressure gradients upon the microcirculation and the metabolism of the cerebral mantle.

Also the clinical manifestations of NPH may be due to several mechanisms, which may operate independently or together, either simultaneously or in sequence.

1. Ventricular enlargement gives distension of long fibre tracts and nuclei in proximity to the ventricles.
2. (Metabolic) hydrostatic pressure-induced atrophy of the periventricular white matter.
3. Effects upon microcirculation and metabolism of the cerebral mantle with decreased CBF.

3. MODE OF ACTION OF CSFP-CBF AUTOREGULATION

3.1 Autoregulation of cerebral circulation

Autoregulation has been defined, in a broad sense, as the capability of an organ to regulate its blood supply in accordance with its needs. More often, however, the term has been applied, in a restrictive sense, to the intrinsic tendency of an organ to maintain constant blood flow despite changes in perfusion pressure.

Autoregulation is particularly well developed in the cerebral circulation. CBF is maintained relatively constant in the face of changes in perfusion pressure within certain limits. The perfusion pressure is the difference between the mean arterial blood pressure (MABP) and the pressure in the intracranial veins which is almost identical with the intracranial pressure (ICP), because these vessels are thin-walled and elastic. Normally the cerebral venous pressure is only a few millimetres of mercury, and MABP is in fact the commonly applied measure of the perfusion pressure.

In the cerebral circulation, the first observations of autoregulation were made by Fog in the thirties (Fog 1934, 1939) in his classic studies of the cat's pial vessels. From 1945 onwards, when the Kety Schmidt method became available as the first reliable technique for measurement of CBF in man, many studies have been done on the effect of blood pressure alterations on the brain circulation. In Lassen's review from 1959, the concept of cerebral autoregulation in man was finally established and it was demonstrated that there was a lower blood pressure limit below which autoregulation becomes inadequate and flow decreases. The upper limit of CBF autoregulation, i.e. the blood pressure level beyond which autoregulation fails and flow increases, has been identified in animal experiments by Ekström-Jodal et al. in 1971. Now we know that the blood flow of normal human brain is relatively stable despite alterations of MABP in the range of about 60 mmHg and 160 mmHg (Fig.

VI) (Strandgaard et al. 1975). These limits are valid in normocapnia. In hypercapnia there is a shift upwards and vice versa (Paulson et al. 1972).

Autoregulation requires a certain amount of time. When the blood pressure changes, time is needed for the cerebral circulation to adjust. This time varies according to the literature from 30 seconds (Ekström-Jodal et al. 1970) to 2 minutes (Rapela and Green 1964).

Blood pressure autoregulation is disturbed frequently in acute brain disease such as a stroke or head injury (Paulson 1971) and in hypertension (Strandgaard 1978). In patients with longstanding hypertension the range of perfusion pressures within which normal pressure-flow regulation exists, is shifted to the right, so that constant levels of CBF are maintained at higher perfusion pressures than found in patients without hypertension.

Autoregulation occurs in response to changes in perfusion pressure produced by increasing or decreasing arterial blood pressure or, on the other hand, by increasing or decreasing CSFP termed "CSFP autoregulation". It appears proven that under normal physiological conditions, as ICP is raised, CBF is *maintained constant until CSF pressure exceeds a critical level.*

Experimental observations indicated that when fluid was infused into the CSF pathways, CBF did not alter until CSFP was elevated to approximately 60-100 mmHg, thereafter further increases of CSFP led to a progressive reduction of CBF (Zwetnov 1970, Johnston et al. 1972). Under normal conditions cerebral vessels dilate as CSF pressure increases with reduction of cerebrovascular resistance so that CBF remains constant. Eventually the autoregulation process fails as intracranial pressure increases further and CBF is reduced.

Autoregulation is thought to be a feature of the smaller resistance vessels, i.e. the arterioles and small arteries.

The demonstration of autoregulation to raised ICP (Häggendal et al. 1970, Jennett et al. 1971) would seem to rule out tissue pressure as a determinant factor in CBF autoregulation. In a severely damaged brain, flow may be unchanged during blood pressure rise because a parallel rise in intracranial pressure leaves perfusion pressure unchanged - a phenomenon which has been called "false autoregulation" (Miller et al. 1975).

A considerable number of experiments has been made on the effects of raised ICP on CBF. Wolff and Forbes (1928), using the skull window technique in the cat, observed that the pial arteries and veins dilated as CSFP increased and that this continued until the ICP was restored to normal.

The link between increased ICP and impaired brain function may be the CSF

(Brock and Jennett 1975).

Gobiet et al. (1975) found that in head-injured patients increasing ICP or decreasing MABP led to a fall in CBF. In a comparable group Kelly et al. (1975) failed to demonstrate a clear relationship between ICP and CBF. The lack of correlation between ICP and CBF was also demonstrated by Enevoldsen and Jensen (1976). They thought that intracranial hypertension did not limit CBF, at least not if ICP was kept below 45 mmHg. In patients with brainstem symptoms but without signs of cortical lesions a positive correlation between ICP and CBF was found. These clinical data are relevant in connection with the results of Johnston and Rowan (1975) who induced intermittent waves of intracranial pressure in baboons. Relatively adequate CBF levels were maintained during episodic increases in ICP, despite marked changes in cerebral perfusion pressure.

However, if autoregulation has been damaged by previous ischaemic episodes, less excessive rises in pressure, such as plateau waves, can lead to reduction of CBF.

The ICP/CBF relationship may vary with the cause of the increased ICP (intracranial mass, oedema, increased CSF volume). Lewis and McLaurin (1972) demonstrated this in rhesus monkeys.

Di Mattio et al. (1975) found that in acute kaolin obstructive hydrocephalus in cats, in which an elevated mean CSF pressure of 20-25 mmHg has been recorded, there is a significant decrease in CBF.

In the chronic stage CSF pressure returns to the normal range of 4 cmH_2O and CBF is generally restored. A gross correlation could be made between the general physical condition and CBF. It should be noted that increased CSF pressure in the acute hydrocephalic cats did not reach the high levels reported to be necessary to reduce CBF of normal animals (Zwetnov 1970). It seems, therefore, that since systemic blood pressure of these animals was unaffected, it may be assumed that the rate of volume change occurring intracranially, coupled with a possible impairment of the cerebral autoregulatory mechanism could result in lowered CBF. There are few references which deal with the effect of lowering CSFP on CBF. Early but prescient observations were made by Forbes and Nason in 1935. They found that reduction of ICP by removal of CSF caused dilatation of the pial veins and venules but prompted constriction of the pial arteries. Haggendal et al. (1970) observed in dogs that CBF was maintained constant even when CSFP became negative.

The first clinical study on the effects of lowering CSFP on CBF was carried out by Shenkin et al. (1948). They showed that reduction of increased

ICP by removal of CSF in patients with brain tumour caused no change in CBF. More recently it has been reported that lowering CSFP by removal of CSF in patients with benign intracranial hypertension (Mathew et al. 1975b) or stroke (Meyer et al. 1977) did not alter CBF. Meyer et al. (1977) measured cerebral hemispheric blood flow before and after withdrawal of 20-30 ml of CSF in 8 patients with recent cerebral infarction and in 4 patients with Alzheimer's disease. After CSF removal the CBF decreased significantly in the Alzheimer's disease group but showed no significant change in the stroke group.

Greitz (1969) suggested that reduced CBF resulting from ventricular distension should produce the signs and symptoms of NPH. There have subsequently been several reports on reduced CBF in cases of NPH with prompt increases towards normal after CSF shunting. Greitz (1968) studied 21 patients with NPH and was able to demonstrate an increase in the flow postoperatively. The blood flow of the grey matter had especially increased.

Salmon and Timperman (1971) demonstrated that ventriculoatrial shunting of the CSF in some patients with post-traumatic hydrocephalus resulted in significant improvement in their clinical state without any appreciable change in ventricular size; an increase in CBF in these patients was demonstrated, though. The hypothesis has been advanced that the clinical improvement is the result of increasing CBF. This increase in blood flow to non-functioning or damaged neurons permits them to regain function.

In patients with NPH, the normal CSFP-autoregulation has been impaired, and when CSF is removed CBF increases, particularly in frontal regions.

Raichle et al. (1974) and Mathew et al. (1975a) independently reported that rCBV and rCBF in patients with NPH respond differently to lowering CSFP from patients with cerebral atrophy. Since small changes in CSFP within the range of normal autoregulation have produced significant increases in CBF in NPH patients, it is postulated that a form of dysautoregulation of CBF in relation to CSFP exists in these patients. In support of this view is the overall loss of autoregulation reported by Heilbrun et al. (1972) in patients with hydrocephalus complicating SAH. This dysautoregulation may also be offered as an explanation for the temporary worsening of the clinical status after PEG in NPH patients.

Raichle et al. (1974) measured CBF and CBV in 8 patients with dementia before and after a reduction in ICP by lumbar puncture, 3 patients with presumed NPH and 5 with atrophy. In the patients with NPH both CBV and CBF increased.

Mathew et al. (1975a) made measurements of rCBF and rCBV after serial intracarotid injection of Xenon 133 and Technetium 99 in a steady state before and after lowering CSFP in 15 patients with NPH and in 10 patients with hydrocephalus ex vacuo. Maximal reduction of rCBF and rCBV occurred in the territory of the anterior cerebral artery in NPH but not in dementia due to brain atrophy. In each patient 30-40 ml of CSF was removed, until the CSFP had been reduced by approximately 50% of the opening pressure, which did not exceed 211 mmH_2O. Since mean arterial blood pressure remained constant, the CSFP change was the only factor that contributed to change in cerebral perfusion pressure. Both CBF and CBV increased after lowering the CSFP by lumbar puncture in 15 patients with NPH but not in the 10 patients with cerebral atrophy. The preoperative mean rCBF and the percentage of increase of mean rCBF after lumbar puncture were correlated with the clinical results of CSF shunting. The higher the preoperative mean rCBF the better the clinical recovery after shunting. The greater the increase in CBF after CSF removal by LP the better the clinical improvement after shunting. These correlations were almost linear. In the majority of cases the upper frontal and postcentral areas showed maximal increase in rCBF after lowering CSFP.

Ingvar et al. (1975) confirmed reductions of rCBF in the frontal, premotor and postcentral regions in addition to reduced mean hemispheric blood flow in 6 patients with NPH.

Hartmann and Alberti (1978) estimated rCBF and rCBV in 29 patients with communicating hydrocephalus (CH) and in 23 patients with arteriosclerotic and presenile dementia (with cortical atrophy). In both groups ischaemic patterns were detected which did not allow any differential diagnostic separation between the patients. In 21 patients with CH and 11 patients with dementia CSFP had been lowered by 30%. In 15 out of 21 patients with CH reduction of CSFP resulted in increase in rCBF and rCBV. This was not achieved in the 11 patients with dementia. Also after ventriculoatrial shunt in some patients with CH an increase in rCBF and rCBV was seen.

Grubb et al. (1977), however, found changes in CBF, after lowering the CSFP, to be of no help in differentiating 11 patients with NPH (10 of these had idiopathic NPH) from 19 patients with cerebral atrophy; CBF increased significantly in both groups of patients.

Also Kushner et al. (1984) found that CBF did not increase after lumbar puncture in 19 patients with NPH, and the measurements were not useful in predicting the outcome of ventricular shunt therapy. Postoperative CBF did not increase after successful shunting.

On the other hand, in the Baylor Laboratories (Meyer et al. 1977) rCBF measurements have proved to be of value not only in establishing the diagnosis of NPH after CSF removal, but also in monitoring patients with NPH after ventricular shunting procedures, since serial rCBF measurements show a progressive reduction of rCBF, particularly in the frontal regions if the shunt is not functioning satisfactorily.

If the shunt is revised and functions well, rCBF returns to normal. On the other hand, CBF decreased (Meyer et al. 1977) in patients with Alzheimer's disease when CSF was removed.

Gelmers (1978) investigated rCBF in one patient with NPH after head injury by means of the intracarotid Xe^{133} method. The regional flow pattern was normal. After lumbar puncture an increased CBF of 19.9% was found. Shunting therapy in this patient had a fair postoperative clinical result.

3.2 CSFP-CBF autoregulation

It is interesting to speculate because of which causes the increase in CBF after a lumbar puncture or a ventriculoatrial shunt has lowered the ICP in patients with NPH. This is hypothesized by Salmon and Timperman (1971). The pressure differential between the carotid artery and the intracranial veins causes the blood to flow (Fig. VII). It is postulated that the venous pressure approximates the ICP and is also reduced by the shunt. For example, if the carotid artery perfusion pressure is 120 mmHg and the CSF pressure is 10 mmHg, the pressure differential between artery and vein is 110 mmHg. After shunting the ICP and venous pressure are lowered to 3 mmHg (Fig. VII). The pressure differential between the carotid artery and the vein is now 117 mmHg, a difference of only 7 mm. It seems unlikely that this small change in the pressure differential would have any significant influence on the flow. According to Brock (1970), who believes that the pressure at the level of the capillary - the tissue perfusion pressure - has the most pertinent influence on CBF, this can be resolved. He estimated this to be 30 mmHg. The pre-shunt pressure differential between this tissue perfusion pressure and the venous pressure would be 30 minus 10 mmHg (=20 mmHg) (Fig. VII). After the ICP has been decreased to 3 mmHg, the pressure differential has increased to 30 minus 3 mmHg (=27 mmHg). This increase in the pressure differential from 20 to 27 mmHg represents a 35% change and it is conceivable that a pressure change of this magnitude could have a significant effect on the CBF. Salmon and Timper-

man (1971) and Brock et al. (1970) believe that this mechanism which causes increase in the pressure differential is responsible for the increase in CBF after shunting. Earlier investigations concerning the effects of manipulating the CSFP showed that the pial arteries dilated as CSFP increased (Wolff and Forbes, 1928) and that in patients with brain tumour CBF was unaltered until CSFP increased above 33 mmHg (Kety et al. 1948). Recent experiments showed that CSFP autoregulation remained intact when ICP was increased to a level of 60 mmHg by inflating a supratentorial balloon. On the other hand, CSFP autoregulation disappeared when ICP had been increased by means of inflating an infratentorial balloon with resulting compression of the brainstem (Johnston et al. 1973), which suggests that CSFP autoregulation is mediated by neurons via brainstem centres.

Now we will consider how CSFP autoregulatory mechanisms may function. Since the cerebral venous system has the lowest intramural pressure with the least rigidity of vessel walls, the walls of the cerebral veins may be assumed to be the site most sensitive to changes in CSFP, tissue pressure or ICP and this may be the site for initiation of the autonomic reflexes responsible for preserving CSFP-CBF autoregulation (Shenkin et al. 1948, Schulman and Verdier 1967, Meyer et al. 1977). For example, the cerebral vasoconstriction that maintains CBF constant after lowering CSFP may be mediated via a "veno-arterial neurogenic reflex" (Meyer et al. 1977). This hypothesis appears to be supported by the following observations.

In early studies utilizing the skull window technique, it was demonstrated that removal of CSF from the cisterna magna caused dilatation of the cerebral veins and venules and a constriction of the pial arteries (Forbes and Nason 1935). Similar venivasomotor reflexes have regularly been observed in many tissues other than the brain, including the digits (Yamada and Burton 1954), the kidney (Haddy 1956) and the leg (Haddy 1956). There appears to be a general rule throughout all tissues measured, including the brain, that distension of the venous vessel wall, by either decreasing tissue pressure or increasing venous pressure, seems to cause a reflex arteriolar constriction mediated over nervous pathways (Haddy 1956, Bannister 1971).

However, cerebral venous distension due to raised ICP or CSFP seems to cause dilatation of the cerebral arteries (Wolff and Forbes 1928) while cerebral venous hypotension brought about by lowered ICP seems to cause vasoconstriction of cerebral arteries (Forbes and Nason 1935). Thus changes in CSFP in either direction cause the pial veins and venules to dilate. On the other hand, the pial artery responses to change in ICP appear to be different; they

dilate when pressure increases but constrict when pressure decreases.

It seems paradoxical that the pial veins dilate as a result of both reduced and increased states of CSF pressure, while the pial arteries behave quite differently in response to the two situations.

However, it is possible that in these two situations the intraluminal pressures in the cortical veins are different, although they appear to be dilated on external observation. For example, during intracranial hypertension with elevated CSFP, the pial venous dilatation may result from compression and closure of the veins near the sinuses, accompanied by distension and high intraluminal venous pressure.

On the other hand, although the pial veins dilate, their intraluminal pressure remains low during reduced intracranial and CSF pressure. In the latter situation the cerebral veins probably dilate in order to maintain intracranial volume constant.

If there was no CSFP-CBF autoregulation, an increase in ICP would decrease cerebral perfusion pressure and CBF, and a decrease in ICP would increase cerebral perfusion pressure and CBF.

However, in the normal animal with intact CSFP-autoregulation, dilatation of pial veins occurs irrespective of CSFP having increased or decreased, but the pial arteries constrict when CSFP is decreased and dilate when CSFP is increased and thereby maintain CBF constant. Therefore, it is the pial arteries (or resistance vessels) that ultimately regulate blood flow in response to changes in ICP.

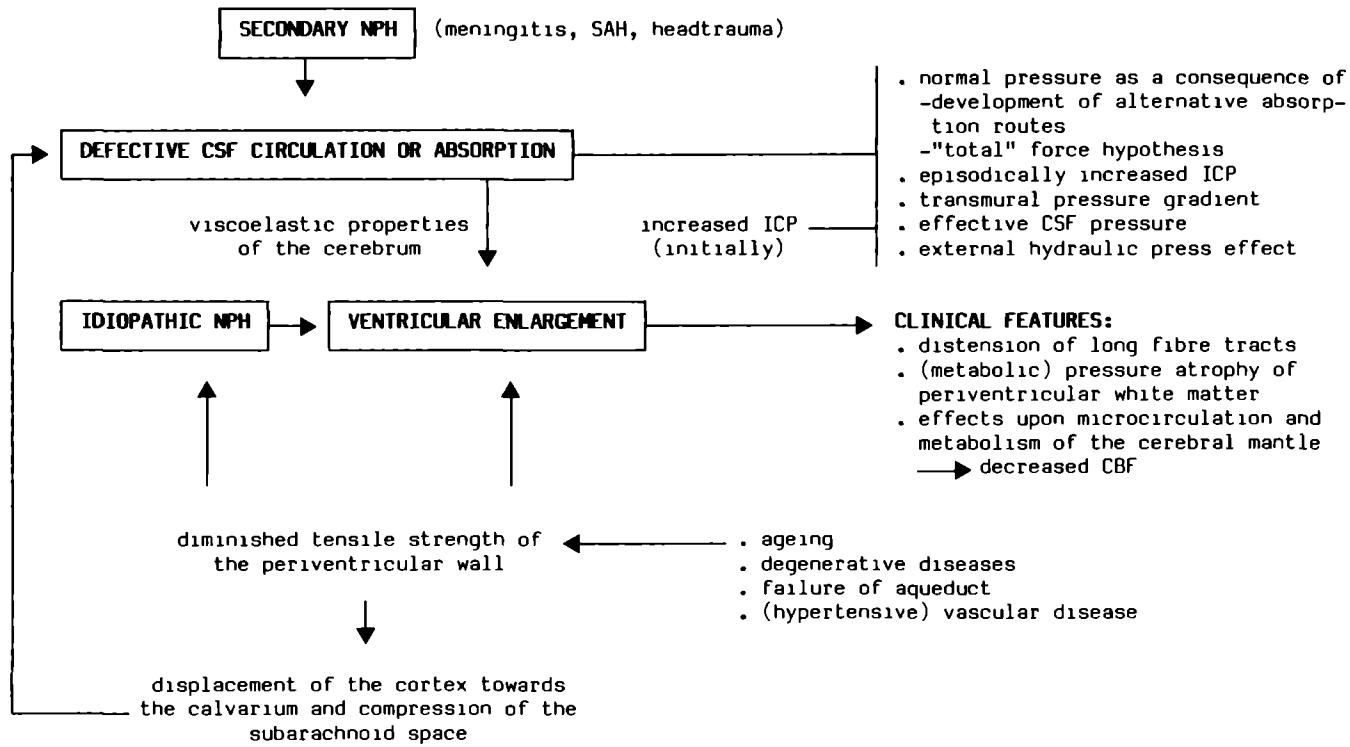
Other evidence to support the hypothesis of a "venoarterial neurogenic reflex" has been derived from perusal of continuous records of cerebral arteriovenous oxygen differences in man during CSF removal where it was noted that the latent period for the development of CBF change following withdrawal of CSF appeared to occur within a few seconds (Meyer et al. 1977). Similar rapidly occurring venoarterial reflexes have been observed in many organs other than the brain (Yamada and Burton 1954, Haddy 1956, 1956).

It has been suggested that the initial site of the venoarterial reflex is a putative basoreceptor in the cortical vein or cerebral sinuses (Mchedlishvilli and Ormotsadze 1962). The anatomical pathways of the hypothetical venoarterial reflex have not been identified. Miller et al. (1973) demonstrated that CSFP-CBF autoregulation is correlated with the presence or absence of blood pressure-CBF autoregulation. In the study of Miyakawa et al. (1977), however, the reflex was preserved after embolic occlusion of middle cerebral arteries in baboons. Mchedlishvilli and Ormotsadze (1962) also suggest that

the CSFP venoarterial reflexes in the brain are resistant to cerebral ischaemia unlike the blood pressure autoregulatory mechanisms which are readily disordered by cerebral ischaemia.

The hypothesis that CSFP autoregulation is influenced by neurotransmitter systems appears to be supported by the study of Miyakawa et al. (1977). They measured CBF before and after withdrawal of 5-6 ml of CSF in 17 baboons. The measurements were made before and after infusion of tyrosine, the precursor aminoacid of dopamine and norepinephrine in the brain. In the steady state CBF was unaltered following reduction of ICP by removal of CSF. However, after infusion of tyrosine, CBF decreased after withdrawal of CSF. The mean arterial blood pressure did not change by withdrawal of CSF either before or after tyrosine infusion. Thus, after tyrosine infusion, CSFP-CBF autoregulation impairs and this supports the hypothesis that CSFP autoregulation is influenced by neurotransmitter systems.

Table VIII.


SECONDARY NPH
(meningitis, SAH, headtrauma)
DEFECTIVE CSF CIRCULATION OR ABSORPTION
. normal pressure as a consequence of
-development of alternative absorption routes
-"total" force hypothesis
. episodically increased ICP
. transmural pressure gradient
. effective CSF pressure
. external hydraulic press effect
viscoelastic properties of the cerebrum
increased ICP (initially)
IDIOPATHIC NPH
VENTRICULAR ENLARGEMENT
CLINICAL FEATURES:
. distension of long fibre tracts
. (metabolic) pressure atrophy of periventricular white matter
. effects upon microcirculation and metabolism of the cerebral mantle
decreased CBF
diminished tensile strength of the periventricular wall
. ageing
. degenerative diseases
. failure of aqueduct
. (hypertensive) vascular disease
displacement of the cortex towards the calvarium and compression of the subarachnoid space

Chapter IV

MATERIALS AND METHODS

As is shown in the previous chapters, review of the literature indicates that diagnostic approaches such as PEG, radioisotope cisternography, CSF infusion test and CT-scan are not reliable in predicting which patients with NPH will benefit from CSF shunting. There is a need for improved tests that will be an aid in diagnosis and assist in predicting the results of CSF shunting in these patients.

There have been several reports of reduced CBF in cases of NPH with prompt increases towards normal after lowering CSFP by means of lumbar puncture and/or CSF shunting. This increase in CBF is associated with clinical improvement and reduction in the size of the ventricles. The technique used for these CBF studies was the intra-arterial radioisotope method of Lassen and Ingvar (1961).

However, this technique has severe limitations; it is invasive and even the inhalation method of Mallet and Veal (1965) and the intravenous method of Thomas et al. (1977) require a certain amount of patient co-operation. The complexity of the apparatus and the relatively high amount of radioactivity make these techniques unsuitable for bedside use and in general neurologic practice.

It is difficult to study rapid changes of CBF because of the length of the wash out curves necessary for computer analysis.

These reports and findings prompted us to study patients with NPH by means of the more simple and innocuous ultrasonic Doppler technique that reportedly gives an indication of changes in mean CBF. The results of this technique have to be considered only as semi-quantitative, but the necessary equipment is simple and can be used at the bedside. The procedure requires only a gentle stable hand of the investigator, but almost no patient co-operation. It is very easy to study rapid changes of CBF with this technique.

For Doppler examination the common carotid artery is measured 2 cm above the clavicle, with a probe-angle of 30-40 degrees. According to Mol (1973), the velocity/time curve of the common carotid artery (CCA) consists of a systolic and a diastolic phase. The mean velocity during the systolic phase is determined by the perfusion pressure, the diameter of the CCA and the vascular resistance in the bed of the internal and external carotid arteries. However, during the mid-diastolic period there is practically no flow through the external carotid artery and in this period the flow through the common carotid artery is determined by the flow through the internal carotid artery

only.

Jonkman et al. (1978) studied the relationship between blood flow velocity and CBF in man. The blood flow velocity (BFV) can be calculated from the measured Doppler shift (ΔF), the emitter frequency (F), the angle of the probe (α) and velocity of sound in tissue (C).

$$1)\ BFV = \frac{C.\Delta F}{2F.\cos\alpha}$$

The blood flow through the internal carotid artery (BFC) or through the common carotid artery in the mid-diastolic period is the product of the diameter surface ($\frac{1}{4}\pi d^2$) and the mean blood flow velocity (BFV).

$$2)\ BFC = \frac{\pi.d^2.BFV}{4} \quad \text{or} \quad 3)\ BFV = \frac{4.BFC}{\pi d^2}$$

Combining of 1) and 3) leads to:

$$4)\ \Delta F = \frac{8.BFC.F.\cos\alpha}{\pi d^2 C} = \frac{K1.BFC.\cos\alpha}{d^2} \qquad (K1 = \frac{8.F}{\pi.C})$$

The angle α between probe and vessel is intra-individually rather constant. If we also acknowledge the fact that the diameter of the common carotid artery seems to vary little with changes in mean arterial blood pressure and intracranial pressure, we can write for 4):

$$5)\ \Delta F = K2.\ BFC \quad (K2 = \frac{K1.\cos\alpha}{d^2})$$

This means that a linear relationship can be expected between changes in blood flow and the accompanying changes in measured Doppler shift, as long as we take only intra-individual changes in ΔF (diastolic) and BFC into consideration.

The hypothetical relationship between BFV and CBF in humans was tested by Jonkman et al. (1978) in 2 ways. If such a relationship exists there must also be a linear relationship between changes in Ap CO_2 and BFV, because the relationship between Ap CO_2 and CBF is a linear one (Høedt Rasmussen 1967). This was tested in 19 young healthy adults and indeed, a linear relationship between changes in Ap CO_2 and BFV in the common carotid artery during the mid-diastolic period was found.

Secondly, Jonkman et al. (1978) studied the relationship between changes in mean blood flow velocity and changes in the mean rCBF as measured with

Xenon-133 injected intra-arterially.

Changes in rCBF were induced by injection of papaverine into the internal carotid artery. This was done in 4 patients. An induced increase up to 150% of the resting value in mean rCBF resulted in a mean increase of 154% in mid-diastolic flow velocity. It appeared that the relationship between increases in CBF and BFV was poor if the BFV was calculated from the Doppler shift during the systolic period, but was rather good when the BFV was measured during diastole. Jonkman confirms the hypothesis that Doppler shift measurements can be used as a simple technique for monitoring changes in mean CBF.

2. THE DOPPLER-LP TEST

All patients studied in this thesis underwent the Doppler-LP test. For this investigation, a Parks directional Doppler device, model 806, was used. The signals were registered on an Elema Schönander electroencephalograph. The gauge was such that 1250 Hz of the Doppler device gave a pen deflection of 2 cm. The frequency response of the device is 5 MHz. Doppler haematotachography of the right common carotid artery was performed. This technique was applied directly before and 5 minutes after lowering CSFP to zero by removal of 30-40 ml CSF by means of lumbar puncture with the patient in lateral recumbent position. Cardiac frequency and blood pressure were also measured during the registration and were unchanged.

The results of typical systolic and diastolic flow velocity curves of the common carotid artery are given in figure VIII. Three parameters may be extracted from this curve, the systolic value S and 2 diastolic values D_1 and D_2. The values were measured as soon as the registration showed a stable curve. The Doppler-LP test was considered as "positive", if the diastolic values each increased 2 mm or more and as "negative", if the increase was less than 2 mm, 20 minutes after lumbar puncture. The measurements were always performed between 2-4 p.m. by the author and a laboratory assistant. The curves were interpreted by two skilled electroneurologist (E. Colon, H. Vingerhoets).

3. AIMS OF THE STUDY

Aims of our study are:

1. To end the clinical confusion of arguments for indication of shunting in patients with NPH.
2. To find a reliable indicator for shunting.
3. To evaluate the clinical applicability of the Doppler-LP test.
4. To evaluate the Doppler-LP test in a non-hydrocephalus population.
5. To study the predictive value of the Doppler-LP test in a group of shunted NPH patients.
6. It was not the direct aim of the study to investigate the predictive value of the Doppler-LP test in a population with hydrocephalus that was not shunted

4. PATIENTS

The Doppler-LP test was performed after receiving verbal consent of the patient and/or his relatives. The procedure was in accordance with the guidelines set by the hospital's ethical committee.

Two groups of patients were examined with the Doppler-LP test:

Group A: The control group consisted of 25 neurological patients aged 13-71 without internal hydrocephalus who had to undergo LP for diagnostic purpose.

Group B: A group of 91 patients, consecutively passed between October 1976 and February 1985, suspected by their neurologist(s) of having a NPH syndrome. In 3 patients the Doppler-LP test could not be evaluated because of total restlessness or tachycardia with cardiac irregularity. These patients have not been operated on and have not been included in the study.

5. DIAGNOSTIC PROCEDURES FOR HYDROCEPHALUS: CT SCAN, PEG, ARTERIOGRAPHY

Internal hydrocephalus was determined by means of different neuroradiological techniques such as PEG and arteriography, but mostly by CT scan (since 1978). The CT equipment that was used was of the Delta 50-FS (Ohio-Nuclear). Scanning was done parallel to the canthus meatus plane with joining sections of 8

mm. The CT scan recordings were interpreted by two neuroradiologists (H. Thijssen and J. Merx).

Internal hydrocephalus on CT was defined as ventricular dilatation with a cerebroventricular index of the bifrontal diameter ≥ 0.38 in patients younger than 20 years of age and ≥ 0.40 in adults (Hahn and Rim 1976).

Cortical atrophy on CT was judged as absent or present (slight or severe). Dilatation of third and/or fourth ventricle on CT and PEG was also taken into account, as was periventricular oedema.

For evaluating CT patterns, we also used the score chart published by Gado et al. (1976). As indicated in table IX, the total score is the algebraic sum of the values given to each of the CT findings. A dilated fourth ventricle scores higher than a dilated third ventricle.

6. OTHER DIAGNOSTIC PROCEDURES

6.1 EEG

In most of the patients an EEG was performed for detecting abnormalities (diffuse slowing, focal changes, generalized dysrhythmias), but also to demonstrate variations of frequency of the occipital (α) rhythm before and after operation. A frequency with an increase greater than 0.5 Hz was recorded as an improved EEG. The EEG was registered on an Elema-Schønander electroencephalograph, using the 10-20 international system for electrode placement. A standard EEG was performed under standard conditions: 30 minutes of wakeful rest with closed eyes, photic and auditory stimulation and 3 minutes of hyperventilation. A semiquantitative description of the different records was made by skilled electroneurologists. In 10 patients a quantitative EEG analysis was used; power density spectra of different regions were performed (occipital, temporal and parietal) with the use of an 8 K PDP 11/10 computer in association with a 24 K PDP 11/45 system. For the alpha average, the EEG recording and analysis technique as described by Colon et al. (1975) was used.

For the purpose of our study it became evident that the findings obtained by computerized techniques and those obtained through visual inspection by skilled electroneurologists were sufficiently comparable to answer our study questions.

6.2 Somatosensory Evoked Potentials (SSEP)

Median nerve stimulation produces a variety of potentials that can be recorded from the scalp. These somatosensory evoked potentials can be recorded with signal averaging techniques and have been extensively investigated (Desmedt and Brunko 1980).

The cortical EP consists of two distinct parts. The first part is the so-called specific cortical reaction, the second one is the aspecific cortical reaction.

The specific reaction is the part that is generated by the thalamo-cortical tract and cortical somatosensory column reaction. It consists of a negative followed by one or more significantly positive parts. After finger stimulation for example, a N20 and then a P_{27} and P_{45} may be found. This specific reaction is normally localized above the specific cortical somatosensory representation of the stimulated body area.

The non-specific reaction consists of at least one positive, negative -and- positive part which is found more or less diffuse over both hemispheres.

Many different peaks are described by various authors, but in general there is at least agreement about the form as described in Fig. IX.

In clinical practice the late SSEP components are used for the examination of the propagation of sensory information over the cortical hemispheres. There are reasons to expect that the late components (those seen 60 msec or longer following the stimulus) change at least when the cortex itself is affected (Colon et al. 1979, Kazis et al. 1982).

So, diseases that are especially bound to the cortical and subcortical neurons ("gray matter") or the large interconnecting cerebral fibres cause changes in the late components of the SSEP.

Lüders (1970) investigated the influence of age on wave form and the latency of the SSEP components. He concluded that the components P_{45}, N_{60} and P_{100} are sensitive to aging, as demonstrated by a progressive increase with age of the latencies of these components. The results of Levy (1971) tend to support the prediction that senile demented patients show a prolongation of the latency of the SSEP's.

Also Huisman et al. (1985) found in patients with senile dementia a significant delay of the middle and long latency potentials compared to healthy volunteers.

This knowledge induced us to perform SSEPs in a small number (n=10) of our

patients with NPH.

SSEP was elicited after right median nerve stimulation at twitch level. For specific components (neck N_{13} and cortical N_{20}, P_{25} and P_{45}) 1000 regular stimuli were given twice with a frequency of 3/s and a bandpass between 5 and 1000 Hz. For later EP components the stimuli were given at random until a frequency of 1/3 s, and a bandpass of 1-250 Hz.

The sample frequency of our equipment (Nicolet CA 1000 or P_2) is 512 points on a full scale.

6.3 Neuropsychological testing

Some patients also underwent psychological examinations to test impairment of mentation (before) and to evaluate mental changes after surgery.

Psychometric testings were carried out a few days before the shunt-operation as well as 14-30 days after, and in some cases 3-6 months and ≥ 1 year after surgery. The investigations were all made by one psychologist (G. Cho Chia Yuen).

Five psychometric methods were used to measure cognitive functions. These methods are the test of Bourdon-Wiersma, the Visual Retention Test of Benton, the Wechsler Memory Scale, the Trailmaking Test and the Wechsler Memory Adult Intelligence Scale. Most patients had 2 or more of these tests.

The degree of cognitive reduction, relative to the estimated premorbid level, is rated on a 6 point scale. Improvement after surgery is defined as a reduction of at least one grade on this 6 point-scale.

6.4 Isotope cisternography

Disturbance in CSF dynamics was investigated in most patients by means of isotope cisternography. Some patients had a PEG with absence of air distribution over the convexities.

Isotope cisternography was performed by injecting 100-150 μ Ci R^{131}IHSA or, from 1980, 500 μ Ci In^{111} DTPA into the CSF by lumbar puncture.

The cisternograms were divided into 4 groups, according, with a slight modification, to Rossi (1974).

Group I : Ventricular filling and retention (stasis) of the isotope after 48 hours.

A: without distribution of the isotope over the cerebral convexities.

B: with distribution of the isotope over the cerebral convexities.

Group II : Ventricular filling and stasis, but also partial clearance of the isotope out of the ventricles after 24 hours and with distribution of the isotope over the cerebral convexities.

Group III: No pictures available after 48 hours. Ventricular filling and stasis of isotope after 24 hours.

A: without distribution of the isotope over the cerebral convexities.

B: with distribution of the isotope over the cerebral convexities.

Group IV : Slightly delayed CSF circulation, no ventricular filling of isotope and a normal cisternogram.

6.5 Cerebrospinal fluid analysis

The lumbar CSF pressure was measured in cmH_2O, with the patient in lateral recumbent position and lumbar puncture was always done between 2-4 p.m. Analysis of protein content, pyruvate, lactate levels and ratio were noted and in some patients also HVA and 5-HIAA levels.

6.6 Epidural intracranial pressure monitoring (EDPM)

We preferred the epidural pressure monitoring above the ventricular pressure monitoring because of the advantage of less risks of infection, catheter blockages and leakage of CSF. We used the epidural pressure-transducer device developed by Beks et al. (1977).

The sensor, a cylinder of 11 mm in diameter, was implanted in a right frontal burr hole under local anaesthesia. The ICP was related to atmospheric pressure.

The ICP was monitored for at least 48 hours in a patient lying flat and still and was recorded on a trendrecorder (speed: 1 gauge/1½ minute). In a number of patients, EDPM could not be performed because the patients with severe mentation disturbance did not co-operate sufficiently, but also because the apparatus was not always available.

In 2 patients we did not succeed because of restlessness. The ICP record-

ing was classified as abnormal (+) if peakpressure exceeded 15 mmHg during a period of at least 10 minutes, especially during sleep overnight (Tans 1979), or if the peakpressure was twice the baseline pressure (Belloni 1976).

7. INDICATION FOR SHUNTING

Most patients were under supervision of clinical neurologists other than the author. Decision on shunting had not been taken by the author. Indication for operation had been made by the patient's neurologist and neurosurgeon in our weekly neurosurgical rounds. All patients were presented there for full discussion.

A firm rule for making an indication for shunting did not exist. Decision as to shunting or not shunting had to be taken by the patient's neurologist and the consulting neurosurgeon.

In their consultation the next factors were taken into account among other things:

1. The clinical signs and symptoms of the patient; i.e. the triad of progressive mental deterioration, gait disturbances and urinary incontinence.
2. Duration of illness and the patient's age; patients older than 70 years of age were discussed especially careful.
3. In addition, in most patients outcome of isotope cisternography, CT scan, and in some patients also outcome of epidural pressure monitoring was taken into account; but never one single outcome was a deciding factor for shunt therapy.
4. In the course of this study (since 1980), the Doppler-LP test had also contributed, to some degree, to the indication for shunting.

So the decision as to shunting or not shunting was based on quite a varying composition of arguments of which the parts had a changing and grading importance.

It is also on the grounds of these facts that we performed the Doppler-LP study.

Of the group of 88 patients with hydrocephalus, 58 patients underwent shunting. All these 58 patients were accepted to have a NPH syndrome.

8. SHUNTING PROCEDURES AND CLINICAL SCORING

All patients had a shunting procedure between October 1976 and February 1985.

The patients were given ventriculoatrial (44 cases) and ventriculoperitoneal (14 cases) shunts. The lateral ventricle was cannulated via a temporo-occipital burr hole on the right side under general anaesthesia. Medium pressure Holter valves were employed in 40 cases, Holter pressure valves in 4, Raymondi peritoneal shunts in 6 and Holter Hausner peritoneal shunts in 8 patients. The decision which type of shunt should be used was made by the neurosurgeon in question. Since 1982 VP shunting was preferred to VA shunting because of less risks of cardiac complications in these elderly patients. Of the 58 patients who underwent shunting, 2 patients died 2 weeks after operation because of respectively pneumonia with renal failure and cardiovascular-respiratory failure.

The other 56 patients were followed for at least three months after shunting. Of these 56 patients the clinical degree of impairment before and after operation was scored by means of rating scales as shown in table X. We used the rating scales for gait, mentation and micturition, according to the model of Fisher (1977), supplemented with points for ADL, extrapyramidal signs, headache, epileptic seizures and consciousness.

The clinical scores were performed by one person, the author.

9. CRITERIA FOR IMPROVEMENT

Clinical improvement after shunting was expressed in a reduction of the preoperative rating points. Improvement was defined as a reduction of at least one grade on the ADL scale plus a reduction of $\geq$ 50% of the total rating points minus ADL points. We used a liberal criterion for improvement, requiring a patient to manifest improvement on the clinical rating scale at some time ($\geq$ 3 months) after surgery. A more stringent criterion for improvement, requiring a patient to maintain improvement until death or during long follow-up period was not used in evaluating the data because this stringent criterion is subject to more confounding effects, such as intervening medical or other neurological diseases, during the long follow-up.

Postoperative follow-up was done 3 months after surgery for clinical rating scales, EEG, CT scan and sometimes for psychological testing.

Controls were repeated during the next follow-up period.

10. SUSPICION OF DRAIN MALFUNCTION

Suspicion of drain malfunction existed when the patient did not improve and the ventricular size on control CT did not decrease. In these cases the shunt-system was controlled by means of ^{99m}Tc pertechnetate radioisotope imaging for evaluating the potency of the shunt. If necessary drain revision was performed until all patients had a functioning shunt.

11. STATISTICAL ANALYSIS

In co-operation with the Department of Statistical Consultation (MSA), statistical analysis were performed with Wilcoxon's two-sample test, the chi-square test and the McNemar test.

Table IX. CT scoring system (Gado)

FINDING	SCORE
lateral ventricles	
normal	0
slightly dilated (index 0.38-0.44)	+1
moderately dilated (index 0.45-0.49)	+2
severely dilated (index $\geq$0.50)	+3
third ventricle	
normal	0
dilated	+1
fourth ventricle	
normal	0
dilated	+2
cerebral sulci	
normal	0
dilated	-2

Table X. Clinical rating scales

RANGE	GAIT	MENTATION	MICTURITION
0	normal gait	normal	normal
1	normal gait, unable to walk tandem	abnormal by history, but 3/3 items recalled at 3 min.	urgency, but continent
2	staggering gait, without falling	2/3 items, orientated as to date	
3	history of falling, Romberg positive	2/3 items, disorientated as to date	incontinent less than once weekly
4	history of falling, unable to stand with feet together	1/3 items, orientated as to place	
5	needs to touch objects in walking, uses cane	1/3 items, disorientated as to place	incontinent more than once weekly
6	uses a walker, takes few steps alone	0/3 items, disorientated as to date	
7	unable to stand	0/3 items, disorientated as to place	incontinent daily
8	needs support in walking	0/3 items, disorientated as to date and place	
9	unable to sit or stand	slight delirium, confusion or nonsensical talk	
10	unable to walk	severe delirium, confusion or nonsensical talk	incontinent regularly

A.D.L.

0 undisturbed
1 untidy
2 needs supervision
3 needs little assistance
4 needs much assistance
5 needs full assistance

Extrapyramidal signs

0 none
1 mild rigidity and akinesia
2 strong rigidity and akinesia
3 tremor and/or dyskinesia

Headache

0 none
1 regular
2 often

Epileptic seizures

0 none
1 < 1 weekly
2 > 1 weekly

Behaviour

0 normal
1 depressive
2 paranoid
3 aggressive

Consciousness

0 normal
1 hypersomnia
2 stupor
3 coma

Chapter V

RESULTS OF THE DOPPLER-LP TEST IN THE CONTROL GROUP

The control group consisted of 25 neurological patients aged 13-71 years without internal hydrocephalus (CT) who had to undergo LP for diagnostic purposes. For their age and neurological diagnoses see Table XI. In this table also a representation is given of the different Doppler-HTG values (in millimetres) before and after lumbar puncture in this control groups.

None of these 25 control patients showed an increase of 2 mm or more in the D_1 and D_2 values after LP. None of these patients had discomfort after the procedure.

Conclusion: the one-sided 95% confidence limit probability that an increase of 2 mm or more in the D_1 and D_2 values is seen in control patients is 12%.

Table XI. Representation of the different Doppler HTG values (in millimetres) before and after lowering the CSFP to zero in the control group of 25 patients with their ages and neurological diagnosis

PATIENTS		BEFORE	AFTER	DIFFERENCE
1. M/48	S	23	23	0
P.V.C. intoxication	D_1	9	10	+1
	D_2	8	8	0
2. F/56	S	20	19	-1
presenile dementia	D_1	11	10	-1
	D_2	9	9	0
3. F/28	S	31	31	0
low back pain	D_1	20	20	0
	D_2	18	19	+1
4. M/27	S	20	20	0
M.S.	D_1	10	10	0
	D_2	8	9	+1
5. M/32	S	33	35	+2
gait disturbance e.c.i.	D_1	17	18	+1
	D_2	14	14	0
6. M/29	S	32	33	+1
headache	D_1	15	14	-1
	D_2	12	12	0
7. M/28	S	36	37	+1
A.V. malformation	D_1	13	13	0
	D_2	9	9	0
8. F/13	S	31	32	+1
head injury	D_1	12	12	0
	D_2	11	11	0
9. M/69	S	25	23	-2
presenile dementia	D_1	7	7	0
	D_2	5	5	0
10. M/59	S	24	20	-4
A.L.S.	D_1	10	8	-2
	D_2	8	7	-1
11. F/40	S	23	20	-3
M.S.	D_1	14	13	-1
	D_2	13	11	-2
12. M/20	S	36	37	+1
head injury	D_1	24	25	+1
	D_2	18	19	+1
13. F/30	S	15	14	+1
headache	D_1	9	9	0
	D_2	8	7	-1
14. F/57	S	25	18	-7
combined system disease	D_1	13	10	-3
	D_2	7	7	0
15. M/64	S	16	16	0
cerebral thrombosis	D_1	8	8	0
	D_2	5	7	+2
16. F/33	S	33	35	+2
multiple congential	D_1	17	18	+1
(vascular) defects	D_2	14	14	0

Table XI. (continued)

PATIENTS		BEFORE	AFTER	DIFFERENCE
17. M/54	S	25	23	-2
cerebral arteriosclerosis	D_1	14	15	+1
	D_2	12	12	0
18. M/22	S	23	22	-1
brain injury	D_1	10	8	-2
	D_2	8	7	-1
19. F/19	S	46	37	-9
headache	D_1	26	25	-1
	D_2	24	24	0
20. M/38	S	38	35	-3
epilepsy	D_1	20	18	-2
	D_2	19	16	-3
21. F/46	S	26	22	-4
presenile dementia	D_1	10	10	0
	D_2	8	8	0
22. F/69	S	10	9	-1
depression	D_1	4	4	0
	D_2	3	3	0
23. M/71	S	10	11	+1
cerebral arteriosclerosis	D_1	5	5	0
with infarction L fronto-parietal	D_2	3	3	0
24. M/62	S	9	8	-1
presenile dementia	D_1	5	4	-1
	D_2	4	3	-1
25. M/41	S	23	25	+2
dysarthria e.c.i.	D_1	11	12	+1
	D_2	9	10	+1

Chapter VI

RESULTS OF A GROUP OF 30 PATIENTS WITH INTERNAL HYDROCEPHALUS (CT) WHO DID NOT UNDERGO THE SHUNTING PROCEDURE

1. DESCRIPTION OF THE PATIENTS

The findings in these 30 patients are summarized in Table XII. Eleven patients are women and 19 patients are men, aged 22-79 years.

Fourteen out of 26 patients had a positive (I^a, I^b, III^a) cisternogram (53.8%); one out of nine patients had a positive (+) extradural pressure monitoring test (11.1%).

2. RESULTS OF THE DOPPLER-LP TEST

Table XIII shows the representation of the different Doppler (HTG) systolic and diastolic values in these 30 patients before and after LP.

Patients Nos. 1-27 did not show an increase of 2 mm or more in the D_1 and D_2 values and therefore they had a negative (-) Doppler-LP test. Patients Nos. 28-30 had a positive (+) Doppler-LP test.

3. FOLLOW-UP

At the end of the study 10 out of 27 patients with a negative (-) Doppler-LP test, had a final diagnosis of (arrested) NPH with a stable course or improvement for several years. Nine out of these 10 patients had a secondary form of NPH. The other 17 patients had an other final diagnosis as is shown in Table XII.

One of them (patient no. 1) underwent surgery elsewhere without success.

In the group of 3 patients with a positive Doppler-LP test, 2 patients showed progressive signs and symptoms of the clinical triad of NPH.

Table XII. Review of 30 patients with internal hydrocephalus, who did not undergo surgery

NO.	SEX	AGE	CLINICAL SIGNS AND SYMPTOMS	CT INDEX	CORTICAL ATROPHY	CISTERNO-GRAPHY	EDPM	DOPPLER-LP TEST	FINAL DIAGNOSIS AND FOLLOW-UP
1.	F	73	dalmadorm abuse slight brain damage mental regression for 4 years, electrotherapy for depression	0.52	+	II	np	-	hydrocephalus ex vacuo, 1½ years later VA drain in an other hospital without improvement
2.	M	46	SAH from vertebral aneurysm, deterioration, gait disturbance	0.50	-	np	np	-	secondary NPH spontaneous recovery
3.	M	56	infantile internal hydrocephalus and macrocephaly after meningitis, Parkinsonian features with gait staggering and history of falling, no deterioration, no urinary incontinence	0.60	-	np	np	-	arrested infantile hydrocephalus, improvement after L-dopa medication during next 5 years
4.	M	35	cerebral injury with R temporal concussion, gait disturbance and mental regression for 1 year, epileptic seizures	0.50	-	I[b]	np	-	secondary posttraumatic NPH, spontaneous recovery with antiepileptic medication and decrease of ventricular size (0.44)

Table XII. (continued)

NO.	SEX	AGE	CLINICAL SIGNS AND SYMPTOMS	CT INDEX	CORTICAL ATROPHY	CISTERNO-GRAPHY	EDPM	DOPPLER-LP TEST	FINAL DIAGNOSIS AND FOLLOW-UP
5.	F	22	severe brain injury 4 years ago, mental deterioration, hypothermia	0.42	-	I[b]	np	-	secondary posttraumatic NPH, after treatment with 5HTP and carbidopa recovery and decrease of ventricular size
6.	M	54	scoliosis, gait disturbance for many years, no deterioration, no urinary incontinence, brain injury 12 years ago	0.50	-	I[a]	np	-	arrested hydrocephalus, spontaneous decrease in ventricular size (0.45) and stable clinical state after 4 years
7.	F	58	alcohol abuse, deterioration and gait disturbance for 2 years	0.48	+	II	np	-	hydrocephalus ex vacuo, improvement after psychiatric treatment
8.	F	47	alcohol abuse, headache	0.42	-	I[a]	-	-	stable clinical condition for 5 years
9.	F	67	5 years ago moderate cerebral headtrauma with basal skull fractures, dementia, apraxia; cerebral angiography showed multiple vascular occlusions	0.46	+	I[b]	-	-	posttraumatic encephalopathy, multiinfarct dementia

Table XII. (continued)

NO.	SEX	AGE	CLINICAL SIGNS AND SYMPTOMS	CT INDEX	CORTICAL ATROPHY	CISTERNO-GRAPHY	EDPM	DOPPLER-LP TEST	FINAL DIAGNOSIS AND FOLLOW-UP
10.	M	25	operation at age of three for Dandy-Walker macrocephaly headache	0.50	-	I[a]	np	-	Dandy-Walker, arrested hydrocephalus
11.	M	35	cerebral headtrauma "coma vigile"	PEG	-	I[b]	-	-	posttraumatic encephalopathy, spontaneous recovery
12.	M	69	mental regression for 2 years	0.44	++	IV	np	-	Alzheimer dementia
13.	F	60	mental regression for 4 years, gait disturbance, urinary incontinence	PEG	+	np	np	-	presenile dementia
14.	M	66	gait disturbance for 2 years, slight mental regression, cerebral angiography: arteriosclerosis, CT: multiple small old infarctions	0.40	+	IV	np	-	multi-infarct dementia
15.	M	61	mental regression and cephalea for 1½ years, angiography: severe cerebral arteriosclerosis	0.50	+	II	np	-	presenile dementia with vascular aetiology; he died 3 years later in the same clinical condition because of cardiac failure

Table XII. (continued)

NO.	SEX	AGE	CLINICAL SIGNS AND SYMPTOMS	CT INDEX	CORTICAL ATROPHY	CISTERNO-GRAPHY	EDPM	DOPPLER-LP TEST	FINAL DIAGNOSIS AND FOLLOW-UP
16.	M	72	hemiparesis R, CVA, 2 years ago hypertension and Parkinsonian features, CT: old infactions in both parietal regions	0.41	+	I[b]	np	-	Parkinsonism, cerebrovascular disease depression; he died 2 years later without any signs of dementia or gait disturbances
17.	M	31	slight mental regression, cerebral concussion 16 years ago	0.53	-	II	np	-	posttraumatic encephalopathy, no progression for 3 years
18.	F	62	half a year ago brain injury with frontal cerebral concussion, frontal syndrome	0.52	-	I[b]	np	-	frontal syndrome, concussion, spontaneous improvement
19.	M	74	since 1½ years mental deterioration and gait disturbances, CVA 5 years ago	0.43	+ pvo	IV	np	-	multi-infarct dementia, depression, slight progression for 2½ years
20.	M	74	3 months ago pneumococcal meningitis mental deterioration, urinary incontinence	0.54	- pvo	II	-	-	secondary NPH, spontaneous recovery

Table XII. (continued)

NO.	SEX	AGE	CLINICAL SIGNS AND SYMPTOMS	CT INDEX	CORTICAL ATROPHY	CISTERNO-GRAPHY	EDPM	DOPPLER-LP TEST	FINAL DIAGNOSIS AND FOLLOW-UP
21.	M	79	gait disturbances and urinary incontinence for 2 months, slight mental deterioration	0.44	+	II	np	-	cerebrovascular insufficiency, spontaneous improvement
22.	F	63	4 months ago intracerebral haemorrhage, hypertension, progressing gait disturbances	0.53	- pvo	I[b]	-	-	arrested NPH after cerebral bleeding, no progression for 2 years
23.	M	64	2 years ago CVA with hemiparesis R, since 1 year mental deterioration and urinary incontinence, CT: infarction in cerebral posterior artery and in basal ganglia	0.50	- pvo	I[a]	np	-	multi-infarct dementia, no progression for 2 years
24.	F	33	15 years ago meningitis, absences, headache	0.48	-	IV	-	-	arrested hydrocephalus after meningitis
25.	F	73	2 years ago hemiparesis L with bilateral infarctions, slight mental deterioration and staggering gait	0.50	+	II	np	-	cerebrovascular insufficiency, no progression for 1 year

Table XII. (continued)

NO.	SEX	AGE	CLINICAL SIGNS AND SYMPTOMS	CT INDEX	CORTICAL ATROPHY	CISTERNO-GRAPHY	EDPM	DOPPLER-LP TEST	FINAL DIAGNOSIS AND FOLLOW-UP
26.	M	73	since 6 months slight mental deterioration and gait disturbances; diabetes mellitus and hypertension	0.50	+ pvo	I^b	np	-	cerebrovascular insufficiency, polyneuropathy, no progression for 1 year
27.	F	45	forgetfulness for 2 years, headache	0.56	-	I^b	-	-	arrested hydrocephalus e.c.i., no progression for 2 years
28.	M	56	rheumatoid arthritis, 4 weeks ago SAH, lowered consciousness and urinary incontinence	0.42	-pvo	np	nd	+	arteriitis in RA, CT: infarction R parieto-occipital, spontaneous recovery
29.	M	64	head injury with subdural haematoma 7 years ago, progressive deterioration, gait disturbances and urinary incontinence, CT: infarctions L and R	0.42	±	IV	+	+	progression of signs and symptoms during the next 6 months, multiple cerebrovascular insufficiency, post-traumatic NPH

Table XII. (continued)

NO.	SEX	AGE	CLINICAL SIGNS AND SYMPTOMS	CT INDEX	CORTICAL ATROPHY	CISTERNO-GRAPHY	EDPM	DOPPLER-LP TEST	FINAL DIAGNOSIS AND FOLLOW-UP
30.	M	72	myocardial infarction, for 1 year mental regression and staggering gait	0.50	+ pvo	I^b	-	+	idiopathic NPH, slight progression of mental deterioration and gait disturbances for the next 6 months, occurrence of urinary incontinence

pvo: periventricular oedema
np : not performed

Table XIII. Representation of the different Doppler HTG values (in millimetres) before and after lowering the CSFP to zero in 30 patients with internal hydrocephalus who did not undergo shunting. The lumbar CSFP in the supine patient is given in cmH_2O.

NO.	SEX	AGE	BEFORE LP S	D_1	D_2	AFTER LP S	D_1	D_2	DOPPLER-LP TEST +/-	CSFP (cmH_2O)
1.	F	73	19	5	5	13	5	4	-	9
2.	M	46	18	8	7	13	6	5	-	20
3.	M	56	19	9	8	23	10	8	-	20
4.	M	35	32	17	16	25	11	10	-	14
5.	F	22	25	9	7	22	8	6	-	6
6.	M	54	25	12	11	22	10	9	-	20
7.	F	58	18	10	4	21	11	4	-	12
8.	F	47	21	11	6	20	10	6	-	14
9.	F	67	30	14	12	25	10	9	-	12
10.	M	25	33	18	14	30	16	12	-	19
11.	M	35	25	14	10	27	14	9	-	16
12.	M	69	15	6	4	15	6	4	-	13
13.	F	60	19	8	6	18	7	5	-	14
14.	M	66	14	6	5	14	6	5	-	16
15.	M	61	18	7	6	20	8	7	-	14
16.	M	72	19	7	6	18	8	7	-	18
17.	M	31	15	7	6	16	6	5	-	19
18.	F	62	18	7	4	17	6	3	-	15
19.	M	74	16	6	5	14	6	5	-	16
20.	M	74	9	4	3	11	3	2	-	18
21.	M	79	11	4	3	12	4	3	-	14
22.	F	63	12	5	4	12	4	3	-	20
23.	M	64	15	5	4	15	6	5	-	15
24.	F	33	26	14	11	21	13	12	-	18
25.	F	73	18	7	5	18	7	5	-	8
26.	M	73	14	6	4	19	7	5	-	12
27.	F	45	28	16	14	28	15	13	-	6
28.	M	56	15	5	4	24	10	9	+	14
29.	M	64	36	12	9	38	15	13	+	16
30.	M	72	18	6	5	23	8	6	+	11

Chapter VII

DESCRIPTION OF THE PRE-OPERATIVE FINDINGS IN 58 PATIENTS WHO UNDERWENT SHUNTING

1. DESCRIPTION OF THE PATIENTS

In Table XIV the 58 patients who were treated with shunting are listed with their age, duration of illness, aetiology and duration of follow-up.

1.1 Aetiology

Twenty-seven patients have idiopathic NPH (46.6%). Thirty-one patients have secondary NPH (53.4%). The list below gives a survey of the different aetiologies.

Idiopathic	n=27 (46.6%)
SAH	n= 9 (15.5%)
Brain injury	n=13 (22.4%)
Meningitis	n= 2 (3.4%)
"Otherwise"	n= 7 (12.1%)

1.2 Age

Table XV gives a representation of the different age of the patients at the time of operation.

Conclusion: the patients with idiopathic NPH are older than those with non-idiopathic NPH (Wilcoxon test $p < 0.001$). Most patients with idiopathic NPH are older than 59 (22 out of 27 patients = 81.5%).

1.3 Duration of illness

Table XVI gives a representation of the different durations of illness. Patients with idiopathic NPH have had a longer duration of illness before shunting than patients with non-idiopathic NPH (Wilcoxon test $p < 0.001$). Patients of 60 years old and up have a longer duration of illness than patients below the age of 60 (Wilcoxon test $p = 0.004$).

1.4 Clinical rating scales

Table XVII gives a representation of the clinical rating scales for gait, mentation, micturition, extrapyramidal signs, behaviour and ADL.

As can be seen in this table, all 58 patients have signs of gait and mentation disturbances. Forty-nine patients have signs of urinary incontinence as well, whereas 9 patients do not show these signs. Extrapyramidal signs have been found in 44 patients.

Six patients have epileptic seizures; five patients in the non-idiopathic group and one in the idiopathic group. Of the 27 patients with idiopathic NPH, 22 had signs of hypertension and/or diabetes mellitus, arteriosclerosis or cerebrovascular disease (81.5%) not diagnosed as the cause of NPH. Table XVIII gives a survey of these findings. As shown in this table, in 14 patients gait disturbance was the first presenting symptom, whereas in 13 patients the first symptom was mental disturbance.

2. RESULTS OF THE DOPPLER-LP TEST

In Table XIX the Doppler (HTG) systolic and diastolic values (in mm) before and after LP are represented in the 58 patients who underwent shunting.

The lumbar spinal fluid pressure (CSFP) in the supine patient is given in cmH_2O.

As is shown in this table, 14 patients had a negative (-) Doppler-LP test and 44 patients had a positive (+) Doppler-LP test. All patients with a positive Doppler-LP test showed an increase of more than 15% in the diastolic values.

3. RESULTS OF ISOTOPE CISTERNOGRAPHY

In Table XX the cisternographic findings are listed of 52 patients who were shunted. In 6 patients cisternography was not performed.

In accordance with the literature we consider classification I^a and III^a as representative cisternography patterns for NPH and group I^b as a mixed form suspective for NPH. We consider group II and III^b as non-conclusive patterns for NPH and group IV as a normal cisternography. Classification IV = negative cisternography. Classification I^a, III^a and I^b = positive cisternography.

4. RESULTS OF EXTRADURAL PRESSURE MONITORING

Extradural pressure monitoring was performed successfully in 37 patients who underwent shunting. In two cases monitoring did not succeed because of the patient's restlessness.

In Table XXI the findings of this test in the 37 patients mentioned above are listed.

As is shown in Table XXI, 9 patients had a negative (-) test and 28 patients had a positive (+) test. In none of the patients there were complications afterwards, such as infection etc.

5. RESULTS OF PRE-OPERATIVE CT SCANNING

In Table XXII the results of CT scanning are listed which was performed in 52 out of 58 patients who underwent a shunting procedure. The cerebroventricular index of the bifrontal diameter is given, as is the dilatation of the third and fourth ventricles. Cortical atrophy is judged as absent (-) or present (slight ±; moderate-severe +).

Dilatation of the third ventricle is seen in 50 out of 52 patients (96.2%); dilatation of the fourth ventricle in 14 out of 52 patients (26.9%). Periventricular oedema is noted in 21 out of 52 patients (40.4%). Cortical atrophy is present in 20 patients (38.5%); slight in 7 patients (13.5%) and moderate-severe in 13 patients (25%).

6. RESULTS OF EEG

In the group of 58 patients who underwent shunting, in 56 patients an EEG had been performed before shunting. The findings of frequency of background activity, diffuse slowing, general dysrhythmias and focal changes (present = +) are listed in Table XXIII.

General dysrhythmias include generalized discharges of irritative and/or slow activities from the brainstem and FIRDA.

Focal changes represent local delta-activity in the (fronto-)temporal region.

Focal changes were seen in 34 out of the 56 patients (60.7%); 26 patients had left-sided changes and 5 patients had a right-sided disturbance; 3 pa-

tients had changes on both sides.

Generalized dysrhythmias were found in 27 out of the 56 patients (48.2%). Diffuse slowing was demonstrated in 42 out of 56 patients (75%). Only two patients had normal records. When we consider only the group of 27 patients with idiopathic NPH we find diffuse slowing in 20 out of 27 patients (74%). Focal changes were found in 19 patients (70%); in 15 patients on the left side, in two on the right side and in two other patients on both sides.

Generalized dysrhythmias were found in 13 patients (48%)

7. RESULTS OF SSEP

Examination by means of SSEP was performed successfully in 10 patients who had been operated on. All these patients had a SSEP examination before shunting and in 7 patients the SSEP was performed again after operation.

In Table XXIV the findings of the SSEP examinations are listed. In 9 out of the 10 patients the P_{300} is not generated. In 7 out of the 10 patients the P_{200} is not generated and in two patients it is delayed. In 6 patients the P_{140} is not generated and in two patients the P_{140} is delayed. The SSEP in all patients is normal up to P_{100}; the P_{100} itself is delayed in 50% of the patients. In 9 out of 10 patients there are severe disturbances in the late SSEP components. In the 7 patients who were examined again after shunting there are no distinct differences between pre- and postoperative findings.

8. RESULTS OF LUMBAR CSF ANALYSIS

As is shown in Table XXV, 39 out of 48 patients (81.3%) had lactate values > 1818 μmol/l. In our laboratory the P_{10}-P_{90} values of lactate are 1377-1818 μmol/l; P_{50} = 1580 μmol/l. All patients had lactate values > 1580 μmol/l.

In our laboratory the P_{10}-P_{90} values of total protein are 242-423 mg/l, P_{50} = 320 mg/l. Twenty-one out of 53 patients had total protein values > 423 mg/l (39.6%). In all these patients transsudation was present.

Thirty-two patients (60.4%) had normal total protein values. Of the idiopathic NPH group (n=25), 11 had a normal protein value (44%) and 14 had values > 423 mg/l (56%).

On the non-idiopathic NPH group (n=28), 21 had normal values (75%) and 7 had values > 423 mg/l (25%).

So the idiopathic NPH group contains more patients with protein values > 423 mg/l than the non-idiopathic group. In our laboratory normal HVA values are 100-350 nmol/l and 5-HIAA values 40-170 nmol/l. Twelve out of 41 patients had HVA values > 350 nmol/l (29.3%).; 2 of them had L-dopa medication. Fourteen out of 42 patients had 5-HIAA values > 170 nmol/l (33.3%).

Table XIV. Description of the patients who underwent surgery

NO.	SEX	AGE	DURATION OF ILLNESS (MONTHS)	AETIOLOGY	FOLLOW-UP PERIOD
1.	F	65	18	idiopathic	12 months
2.	M	45	48	meningitis	9 years
3.	F	25	12	neurofibromatosis	9 years
4.	M	52	48	after operation	1 year
5.	M	70	2	subarachnoid haemorrhage	3 months
6.	F	57	1	subarachnoid haemorrhage	7 years
7.	M	67	24	idiopathic	9 months
8.	F	49	1	subarachnoid haemorrhage	7 years
9.	M	66	6	idiopathic	5 years
10.	M	60	1	subarachnoid haemorrhage	8 years
11.	F	20	36	brain injury	7 years
12.	F	8	4	brain injury	6½ years
13.	F	67	12	idiopathic	6 years
14.	M	20	6	brain injury	6 years
15.	F	48	24	idiopathic	6 years
16.	F	65	18	idiopathic	1½ years
17.	M	63	30	idiopathic	6 years
18.	M	19	3	brain injury	2 years
19.	F	13	6	brain injury	6 years
20.	F	14	6	congenital/cyst	6 years
21.	F	57	2	brain injury	6 years
22.	F	63	12	idiopathic	6 years
23.	M	73	24	idiopathic	2½ years
24.	M	53	18	idiopathic	5½ years
25.	F	56	3	after operation	9 months
26.	F	68	1	subarachnoid haemorrhage	5½ years
27.	M	54	1	meningitis	5½ years
28.	M	16	1	brain injury	5½ years
29.	M	58	2	brain injury	5 years
30.	M	45	1	subarachnoid haemorrhage	5 years
31.	F	52	4	subarachnoid haemorrhage	5 years
32.	F	65	6	subarachnoid haemorrhage	6 months
33.	F	49	24	idiopathic	5 years
34.	F	62	6	after operation	16 months
35.	F	71	1	brain injury	4½ years
36.	F	65	6	after operation	4½ years
37.	M	62	48	idiopathic	4 years
38.	F	69	36	idiopathic	15 months
39.	F	72	18	idiopathic	22 months
40.	F	56	2	idiopathic	4 years
41.	M	73	12	idiopathic	4 years
42.	M	20	13	brain injury	3½ years
43.	M	77	24	idiopathic	1 year
44.	F	52	4	brain injury	3½ years
45.	M	69	24	idiopathic	2½ years
46.	M	65	24	idiopathic	2 years
47.	F	51	4	idiopathic	2 years
48.	M	75	36	idiopathic	2 years
49.	F	78	18	idiopathic	2 years
50.	F	24	3	postanoxic	2 years

Table XIV. (continued)

NO.	SEX	AGE	DURATION OF ILLNESS (MONTHS)	AETIOLOGY	FOLLOW-UP PERIOD
51.	M	75	36	idiopathic	3 months
52.	M	67	36	idiopathic	1 year
53.	F	63	30	idiopathic	1 year
54.	M	76	18	idiopathic	1 year
55.	F	70	24	idiopathic	1 year
56.	M	56	6	brain injury	9 months
A.	F	65	2	subarachnoid haemorrhage	- (†)
B.	M	69	48	brain injury	- (†)

Table XV. Age in years of the patients at the time of operation

	< 20 years	20–29	40–49	50–59	60–69	70–up	N
All (n= 58)	6	4	5	13	19	11	
Males	2	2	2	6	8	7	27
Females	4	2	3	7	11	4	31
Idiopathic (n=27)	0	0	2	3	13	9	
Males	0	0	0	1	7	6	14
Females	0	0	2	2	6	3	13
Not idiopathic (n=31)	6	4	3	10	6	2	
Males	2	2	2	5	1	1	13
Females	4	2	1	5	5	1	18

Table XVI. Duration of illness in months

	1–3	4–11	12–23	24–35	36–up	N
All (n=58)	16	12	11	10	9	
Males	7	3	4	6	7	27
Females	9	9	7	4	2	31
Idiopathic (n=27)	1	2	9	10	5	
Not idiopathic (n=31)	15	10	2	0	4	
< 60 years	12	8	3	2	3	28
≧ 60 years	4	4	8	8	6	30

Table XVII. Clinical rating scales of 58 patients who underwent shunting

NO.	DURATION ILLNESS	GAIT	MENTA-TION	MICTU-RITION	TOTAL TRIAD	EXTRA-PYR.	BEHAVIOUR	ADL
1.	18	8	8	7	23	3	1	4
2.	48	2	6	0	8	1	1	2
3.	12	4	2	5	11	0	1	1
4.	48	2	4	0	6	1	2	1
5.	2	10	10	10	30	0	1	5
6.	1	10	9	10	29	0	0	5
7.	24	5	2	3	10	0	1	3
8.	1	10	9	7	26	0	3	5
9.	6	4	9	10	23	3	2	5
10.	1	8	10	10	28	0	3	5
11.	36	2	2	1	5	1	1	0
12.	4	10	10	10	30	2	3	5
13.	12	5	9	3	17	1	3	4
14.	6	4	4	0	8	0	3	2
15.	24	2	8	3	13	1	1	4
16.	18	8	8	7	23	1	2	4
17.	30	4	4	0	8	3	1	4
18.	3	10	10	10	30	0	0	5
19.	6	2	8	0	10	0	0	4
20.	6	4	2	0	6	0	0	1
21.	2	5	9	7	21	1	3	4
22.	12	2	4	0	6	1	1	2
23.	24	5	9	7	21	2	3	4
24.	18	5	6	10	21	2	1	2
25.	3	8	8	7	23	2	1	5
26.	1	10	10	10	30	2	1	5
27.	1	2	5	10	17	1	1	3
28.	1	2	9	10	21	1	3	4
29.	2	2	9	7	18	1	2	4
30.	1	3	9	5	17	1	3	4
31.	4	10	10	10	30	2	0	5
32.	6	4	4	0	8	2	3	4
33.	24	3	4	0	7	2	1	2
34.	6	5	6	3	14	1	1	4
35.	1	8	9	7	24	1	0	4
36.	6	10	8	10	28	1	0	5
37.	48	4	5	7	16	1	1	3
38.	36	10	8	10	28	2	3	5
39.	18	8	8	10	26	2	0	4
40.	2	5	9	10	24	0	0	5
41.	12	8	10	10	28	1	3	5
42.	13	8	8	7	23	2	1	5
43.	24	4	3	10	17	1	3	4
44.	4	4	9	7	20	1	3	5
45.	24	4	10	7	21	2	3	5
46.	24	4	9	7	20	1	1	4
47.	4	4	8	10	22	2	1	5
48.	36	4	8	5	17	2	3	4
49.	18	5	8	7	20	3	1	4
50.	3	10	10	10	30	2	0	5

Table XVII. (continued)

NO.	DURATION ILLNESS	GAIT	MENTA-TION	MICTU-RITION	TOTAL TRIAD	EXTRA-PYR.	BEHAVIOUR	ADL
51.	36	8	10	10	28	2	3	5
52.	36	5	8	5	18	1	0	4
53.	30	3	6	5	14	3	2	3
54.	18	5	3	5	13	0	0	4
55.	24	8	6	5	19	2	3	4
56.	6	4	3	5	12	0	3	4
A.	2	10	10	10	30	0	2	5
B.	48	8	9	10	27	2	3	5

Table XVIII. Description of 27 patients with idiopathic NPH

NO.	SEX	AGE	FIRST PRESENTING SYMPTOM G = gait disturbance M = mental symptoms	HISTORY OF CONCOMITANT DISEASE
1.	F	65	G	hypertension
7.	M	67	M	hypertension, cardiac failure
9.	M	66	G	-
13.	F	67	M	hypertension
15.	F	48	M	hypertension
16.	F	65	M	arteriogr.: diffuse arteriosclerosis
17.	M	63	G	arteriogr.: diffuse arteriosclerosis
22.	F	63	M	diabetes mellitus, hypertension
23.	M	73	G	TIA, hypertension, diabetes mellitus
24.	M	53	G	-
33.	F	49	M	hypothyroidism
37.	M	62	M	myocardial infarction
38.	F	69	M	hypertension, cerebral infarction
39.	F	72	G	hypertension, diabetes mellitus
40.	F	56	G	TIA, hypertension
41.	M	73	G	ECG: old infarction
43.	M	77	G	hypertension
45.	M	69	M	hypertension, diabetes mellitus
46.	M	65	M	hypertension
47.	F	51	M	-
48.	M	75	G	TIA, hypertension
49.	F	78	G	cerebral infarction
51.	M	75	M	emphysema, chronic bronchitis
52.	M	67	G	hypertension
53.	F	63	M	hypertension, diabetes mellitus
54.	M	76	G	ECG: old infarction; hypertension
55.	F	70	G	hypertension

Table XIX. Representation of the Doppler-(HTG)values before and after LP in 58 patients who underwent surgery

NO.	HTG-VALUES IN MM before LP			HTG-VALUES IN MM after LP			LUMBAR CSFP (cmH_2O)	DOPPLER-LP TEST +/-
	S	D_1	D_2	S	D_1	D_2		
1.	17	7	4	18	8	4	16	-
2.	18	8	6	21	12	11	15	+
3.	25	12	10	38	15	13	20	+
4.	17	9	8	16	10	7	18	-
5.	29	18	16	21	13	11	10	-
6.	18	7	5	25	9	8	20	+
7.	22	10	8	21	10	8	21	-
8.	19	10	9	24	16	15	21	+
9.	32	11	10	34	12	10	10	-
10.	18	8	7	23	13	11	10	+
11.	35	15	13	31	15	13	10	-
12.	24	6	5	30	8	7	18	+
13.	23	10	8	41	22	20	15	+
14.	50	30	27	52	35	30	20	+
15.	20	11	10	17	9	8	16	-
16.	22	10	7	25	13	10	16	+
17.	21	6	4	21	6	4	18	-
18.	22	12	10	32	17	14	16	+
19.	28	12	10	23	15	13	20	+
20.	23	15	12	24	18	15	19	+
21.	30	14	12	36	21	19	14	+
22.	13	5	4	27	14	12	15	+
23.	13	3	2	18	6	5	17	+
24.	23	12	11	32	16	14	16	+
25.	24	11	10	35	15	14	20	+
26.	16	9	8	28	11	10	16	+
27.	22	10	9	38	14	12	16	+
28.	43	18	17	48	31	25	16	+
29.	34	13	9	47	15	12	15	+
30.	11	7	6	17	9	8	21	+
31.	12	6	5	20	8	10	16	+
32.	20	10	9	32	16	13	20	+
33.	20	9	7	35	20	17	10	+
34.	30	14	12	42	20	18	12	+
35.	15	6	4	17	8	7	16	+
36.	20	6	5	20	8	7	16	+
37.	21	9	8	31	14	13	7	+
38.	15	5	4	18	10	9	14	+
39.	15	4	3	15	4	3	10	-
40.	19	8	7	23	11	10	8	+
41.	6	4	3	16	10	9	18	+
42.	28	12	11	34	19	17	12	+
43.	19	6	5	24	9	8	12	+
44.	19	10	8	30	16	15	9	+
45.	18	7	5	19	7	6	15	-
46.	17	8	7	26	14	12	16	+
47.	23	13	12	29	18	16	14	+
48.	20	10	9	26	14	11	13	+

Table XIX. (continued)

NO.	HTG-VALUES IN MM before LP			HTG-VALUES IN MM after LP			LUMBAR CSFP (cmH_2O)	DOPPLER-LP TEST +/-
	S	D_1	D_2	S	D_1	D_2		
49.	16	7	6	19	9	8	19	+
50.	20	8	7	20	8	7	12	-
51.	14	5	4	18	9	7	14	+
52.	12	6	4	11	5	4	18	-
53.	18	5	4	17	4	3	12	-
54.	29	10	8	24	8	7	10	-
55.	14	5	4	21	9	8	11	+
56.	26	10	8	29	13	11	14	+
A.	12	5	4	17	7	6	12	+
B.	22	8	6	27	12	10	14	+

Table XX. Cisternographic findings in 52 shunted patients

	CLASSIFICATION OF CISTERNOGRAPHY					
	I^a	I^b	II	III^a	III^b	IV
PATIENTS	1,3,4,5, 12,14,16, 19,22,35, 36,37,41, 47,49,51, 54,55,56, A	9,15,26, 28,29,32, 38,39,40, 42,43,44, 45,53	2,7,17, 21,33,34, 48,52	10,23,31	11	6,13,24, 46,50,B
	n=20	n=14	n=8	n=3	n=1	n=6

Table XXI. Results of ICP monitoring in 37 patients who underwent surgery

NO.	BASELINE ICP (mmHg) (resting pressure range)	PRESSURE GRADIENTS (mmHg)	CONCLUSION
2.	9-12	-12	-
4.	9-12	20-23	+
5.	3-6	-6	-
7.	12-15	21-24	+
9.	6-9	9-12	-
10.	6-9	15-20	+
11.	12-15	24-27	+
13.	6-9	18-21	+
15.	6-9	15-18	+
16.	10-12	30-36	+
17.	9-12	20-24	+
18.	12-15	25-33	+
20.	9-12	18-21	+
21.	12-15	20-24	+
22.	12-15	24-27	+
24.	12-15	30-35	+
25.	9-12	20-25	+
26.	9-12	25-30	+
27.	6-9	20-24	+
32.	9-12	-12	-
33.	3-6	15-18	+
34.	6-9	18-21	+
35.	6-9	15-18	+
36.	9-12	21-24	+
39.	9-12	15-18	+
44.	6-9	15-18	+
46.	6-9	18-21	+
48.	9-12	-12	-
49.	6-9	15-18	+
50.	12-15	21-24	+
51.	9-12	12-15	-
52.	9-15	24-28	+
53.	6-9	-9	-
54.	9-12	-12	-
56.	6-9	-9	-
A.	9-12	18-21	+
B.	12-15	30-33	+

Table XXII. Results of CT scanning

NO.	BIFRONTAL CEREBRO-VENTRICULAR INDEX pre-op	postop	VENTRICLE DILATATION third	fourth	CORTICAL ATROPHY	GADO INDEX	CLINICAL IMPROVE-MENT
6.	0.45	0.33	+	+	-	5	+
7.*	0.41	0.34	+	-	-	2	-
8.	0.53	0.29	+	-	-	4	+
9.*	0.55	0.42	+	-	+	2	-
11.	0.43	0.35	+	-	-	2	-
12.	0.61	0.44	+	+	-	6	+
13.*	0.45	0.39	+	-	+	1	+
14.	0.58	0.51	+	+	-	6	+
15.*	0.41	0.36	+	-	±	1	-
16.*	0.53	0.40	+	-	-	4	+
17.*	0.43	0.40	+	-	+	1	-
18.	0.52	0.47	+	-	-	4	-
19.	0.50 pvo	0.39	+	-	-	3	+
20.	0.56	0.46	+	+	-	6	+
21.	0.53 pvo	0.47	+	+	-	6	+
22.*	0.45	0.42	+	+	+	4	+
23.*	0.41	0.29	+	-	+	0	+
24.*	0.50	slitv	-	-	-	3	+
25.	0.47	0.29	+	-	-	3	+
26.	0.50	0.35	+	-	-	3	+
27.	0.44	0.32	+	+	-	4	+
28.	0.38	0.26 slitv	+	-	-	2	+
29.	0.63	0.47	+	+	-	6	+
30.	0.53	0.37	+	-	-	4	+
31.	0.59 pvo	slitv	+	-	-	4	+
32.	0.40	slitv	-	-	±	0	-
33.*	0.40	slitv	+	-	±	1	+
34.	0.40	0.33	+	-	-	2	+
35.	0.46 pvo	0.34	+	-	-	3	+
36.	0.54	0.37	+	-	-	4	+
37.*	0.47 pvo	0.44	+	-	±	2	+
38.*	0.46 pvo	0.34	+	-	+	1	+
39.*	0.59	0.48	+	-	+	2	+
40.*	0.51	0.45	+	+	±	5	+
41.*	0.58	0.53	+	-	+	2	+
42.	0.46 pvo	0.43	+	-	-	3	+
43.*	0.48 pvo	0.48	+	-	+	1	+
44.	0.46 pvo	0.39	+	+	-	5	+

Table XXII. (continued)

NO.	BIFRONTAL CEREBRO-VENTRICULAR INDEX pre-op	postop	VENTRICLE DILATATION third	fourth	CORTICAL ATROPHY	GADO INDEX	CLINICAL IMPROVE-MENT
45.*	0.45 pvo	0.34	+	-	-	3	-
46.*	0.52 pvo	0.44 slitv	+ +	- -	- -	4 4	+ +
47.*	0.50 pvo	0.30	+	-	-	4	+
48.*	0.50 pvo	0.48	+	-	+	2	+
49.*	0.41 pvo	0.34	+	-	-	2	+
50.	0.42 pvo	0.42	+	-	-	2	-
51.*	0.51	0.45	+	-	+	2	-
52.*	0.48 pvo	0.38	+	-	+	1	-
53.*	0.48 pvo	0.42	+	+	+	3	-
54.*	0.44 pvo	0.35	+	+	+	2	-
55.*	0.43 pvo	0.27	+	-	+	0	+
56.	0.46 pvo	0.33	+	+	-	5	+
A	0.44 pvo		+	-	-		nd
B	0.71		+	+	-		nd

pvo : periventricular oedema
slitv: slit-ventricles
* : idiopathic NPH
+ : present
- : absent
± : slight cortical atrophy
nd : not determined

Table XXIII. Representation of EEG findings in the patients who underwent surgery (n=56)

NO.	BACKGROUND ACTIVITY (Hz)	SLOWING	FOCAL CHANGES L/R	GENERAL DYSRHYTHMIAS	CLINICAL IMPROVEMENT	POSTOPERATIVE EEG
1.*	9-10	-	+ L	-	- *	the same *
2.	8-8½	+	-	-	-	the same
3.	8-9	-	-	+	+	> 0.5 Hz
4.	9-10	-	+ L	-	-	the same
5.	6-8	+	-	+	-	np
6.	6-7	+	+ R	+	+	≧ 1 Hz
7.*	8½-9	-	-	-	- *	< ½ Hz *
9.*	7-8	+	-	+	- *	the same *
10.	6-8	+	+ L	-	+	np
11.	7-9	+	-	+	-	< ½ Hz
12.	4-7	+	-	-	+	> 1 Hz
13.*	6-7	+	+ L+R	-	+ *	≧ 1 Hz *
14.	8-8½	+	-	-	+	> 1 Hz
15.*	9-10	-	+ L	-	- *	the same *
16.*	7-9	+	+ L	-	+ *	> ½ Hz *
17.*	6-8	+	+ L	-	- *	the same *
18.	5	+	-	-	-	> 1 Hz
19.	7	+	+ R	-	+	> 1 Hz
20.	9-9½	-	+ L	+	+	improved
21.	7-8	+	+ L	-	+	> 1 Hz
22.*	9	-	-	+	+ *	improved *
23.*	8-8½	+	+ L	+	+ *	> ½ Hz *
24.*	9-10	-	-	+	+ *	> 1 Hz *
25.	6-7	+	+ L	+	+	> 1 Hz
26.	4-7	+	+ L	+	+	> 1 Hz
27.	5-7	+	-	+	+	> 1 Hz
28.	5-7	+	-	+	+	> 1 Hz
29.	8-8½	+	+ L	-	+	> 1 Hz
31.	6-7	+	+ L	-	+	> 1 Hz
32.	7-8	+	+ R	-	-	np
33.*	9-11	-	+ L	-	+ *	improved *

Table XXIII. (continued)

NO.	BACKGROUND ACTIVITY (Hz)	SLOWING	FOCAL CHANGES L/R	GENERAL DYSRHYTHMIAS	CLINICAL IMPROVEMENT	POSTOPERATIVE EEG
34.	9	-	+ L	-	+	improved
35.	4-7	+	-	+	+	> 1 Hz
36.	8	+	-	+	+	> ½ Hz
37.*	7½-8	+	-	-	+ *	> 1 Hz *
38.*	6-8	+	+ R	+	+ *	> 1 Hz *
39.*	6-9	+	+ L	+	+ *	> 1 Hz *
40.*	8	+	+ L	-	+ *	> 1 Hz *
41.*	7-8	+	+ L+R	+	+ *	> 1 Hz *
42.	9	-	-	-	+	> ½ Hz
43.*	7-7½	+	+ R	-	+ *	> ½ Hz *
44.	7-8	+	+ L	-	+	> 1 Hz
45.*	7-8½	+	+ L	+	- *	the same *
46.*	8-9	-	+ L	-	+ *	the same *
47.*	7½-8½	+	+ L	+	+ *	> 1 Hz *
48.*	8-8½	+	-	-	+ *	> 1 Hz *
49.*	7-9	+	+ L	-	+ *	> 1 Hz *
50.	2-3	+	-	-	-	the same
51.*	5-7	+	-	+	- *	> 1 Hz *
52.*	7	+	+ L	+	- *	< 1 Hz *
53.*	7-7½	+	+ L	+	- *	the same *
54.*	7½-8	+	-	+	- *	the same *
55.*	8½-9	-	+ L	+	+ *	> ½ Hz *
56.	8-9	-	+ L+R	-	+	> ½ Hz
A.	6-7	+	-	+	+	np
B.	5-7	+	+ L	+	+	np

+: present; -: absent; *: idiopathic NPH; >: faster; <: slower; np: not performed

Table XXIV. Findings of SSEP examinations in 10 patients with NPH

NO.	AGE	N_{13}	N_{20}	P_{25}	P_{45}	P_{100}	N_{140}	P_{200}	P_{300}		CLINICAL IMPROVEMENT AFTER SHUNTING
11.	20	NP	18	28	42	100	170	--	--	severe disturbance	-
13.	67	NP	21	29	48	100	130	188	304	normal	+
AS		NP	21	26	42	100	140	188	308	normal	
14.	20	NP	21^{4}	24^{1}	40	120	228*	334*	--	moderate disturbance	+
AS		NP	20^{6}	22	44	130*	200*	310*	--	moderate disturbance	
16.	65	NP	21^{6}	25^{2}	34	114	--	--	--	severe disturbance	+
AS		NP	21^{4}	28^{1}	34	104	--	--	--	severe disturbance	
19.	13	NP	21^{6}	25	60	118	214*	282*	--	moderate disturbance	+
AS		NP	21^{4}	28	50	130*	220*	300*	--	moderate disturbance	
21.	57	NP	20	27	48	132*	--	--	--	severe disturbance	+
AS			19^{2}	27	43^{8}	148*	--	--	--	severe disturbance	
37.	62		20^{8}	28^{8}	52^{8}	140*	--	--	--	severe disturbance	+
AS			20^{0}	29	56	172*	--	--	--	severe disturbance	
48.	75		20^{8}	26^{0}	45^{2}	108	--	--	--	severe disturbance	+
50.	24	12^{8}	17^{2}	21^{6}	38^{4}	--	--	--	--	very severe disturbance	-
52.	67	14^{4}	20^{0}	26^{4}	45^{2}	148*	--	--	--	severe disturbance	-
AS			21^{6}	29^{4}	--	140*	--	--	--	severe disturbance (increased)	

--: not present
NP: not performed
AS: after surgery
* : delayed

Table XXV. Results of CSF analysis in the patients who underwent surgery

NO.	PROTEIN mg/l (242–423)	LACTATE μmol/l (<1818)	RATIO LACTATE/ PYRUVATE (11.6–15.9)	HVA nmol/l (100–350)	5-HIAA nmol/l (40–170)
2.	340	1780	15.2		
3.	105	2040	21.5		
4.	310	1680	16.2		
5.	275	2520	13.3		176
7.	780	2280	15.7	326	117
9.*	340	2120	13.5	1009	68
11.	230			414	80
12.	230	2300	18.8	118	78
13.	315				
14.	270	1980	14.4		
15.	395	1810	14.6	210	100
16.	700	2030	15.3	597	346
17.	533				
18.	450	2090	14.3	174	243
19.	260	2250	14.2	61	110
20.	300	1800	15.7	341	142
21.	120	2740	14.3	406	200
22.	325	2300	16.1	339	164
23.	610	2070	12.2	307	133
24.	500	2330	14.9		
26.	220	2100	11.9		
27.	685	2510	12.4		
28.	330	1690	15.9	60	55
29.	625	2020	18.4	99	110
30.	175	2080	12.5		
31.	235	2000	12.5	167	136
32.	640	1820	14.4	442	171
33.	320	1800	13.4	288	90
34.	345	1600	12.9	216	157
35.	560	3450	12.9	478	165
36.	500	2550	15.5	302	107
37.	280	1860	13.1	279	136
38.	300	1800	11.3	182	86
39.	435	2100	9.5	246	121
40.	670				
41.	290	1920	13.4	333	243
42.	370	1810	14.8	345	173
43.	800			95	163
44.	320	2280	13.3	185	90
45.*	405	2160	14.8	650	182
46.	340	1860	13.5	159	215
47.	375	1840	14.3	171	58
48.	560	1860	14.2	340	152
49.	525	2010	16.6	906	471
50.	1255	2880	20.9	78	186
51.	650	2160	16.5	614	181
52.	850	2190	17.1	144	99
53.	680	2060	16.3	451	250

Table XXV. (continued)

NO.	PROTEIN mg/l (242-423)	LACTATE µmol/l (<1818)	RATIO LACTATE/ PYRUVATE (11.6-15.9)	HVA nmol/l (100-350)	5-HIAA nmol/l (40-170)
54.	330	2680	13.9	287	154
55.	365	1980	14.1	521	206
56.	345	2080	18.1	303	153
A.	280	2510	14.8	647	149
B.	1210	3010		176	108

* patient treated with L-Dopa

Chapter VIII

SURGICAL RESULTS

1. CLINICAL OUTCOME OF SURGERY

Two patients (A and B) died two weeks after operation, of pneumonia with renal failure and of cardiovascular-respiratory failure, respectively. Of the 56 patients who were followed for at least 3 months after surgery, 39 patients improved (69.6%) according to our criteria for improvement. In Table XXVI rating scales are given for gait, micturition, mentation, extrapyramidal signs, behaviour and ADL, before and after shunting.

1.1 Aetiology and clinical outcome of surgery

Of the idiopathic NPH patients 17 out of 27 patients improved (63%) versus 22 out of 29 patients with non-idiopathic NPH (75.9%). The difference is not statistically significant (χ^2 test).

In the group of patients with non-idiopathic NPH; 75% of the patients with SAH improved; 83% of the patients with brain injury; 50% of the patients with meningitis (n=2) and 71% of the patients with aetiology "otherwise" improved.

1.2 Duration of illness and clinical outcome

In Table XXVII a survey is given of the relation between duration of illness and clinical outcome.

As is seen in this table, 18 patients had a duration of illness $\geq$ 24 months; 8 out of these 18 patients improved (44.4%). Thirty-eight patients had a duration of illness < 24 months; out of these 38 patients 31 improved (81.6%).

Conclusion: significantly more patients with a duration of illness < 24 months improved than with a duration of illness $\geq$ 24 months (χ^2 test p= 0.012). In the group of patients with idiopathic NPH these differences (53.3% versus 75%) are not statistically significant (χ^2 test p> 0.05).

1.3 Age of the patients and clinical outcome

In Table XXVIII the relation between age of the patients and clinical outcome is represented. As is shown in this table 29 patients are $\geq$ 60 years; 18 out

of these 29 patients improved (62.1%); of the 27 patients who are < 60 years, 21 improved (77.8%). These differences are not statistically significant (X^2 test).

Of the patients with idiopathic NPH, 22 patients are ≥ 60 years and 5 are < 60 years old. Also in this group the differences in the improvement percentages (59.1% versus 80%) are not statistically significant (X^2 test).

1.4 Combinations of clinical signs and outcome of surgery

All 56 patients had signs of gait and mentation disturbances. Forty-seven patients had the complete clinical triad, i.e. including urinary incontinence.

In this group 34 out of 47 patients improved (72.3%). Of all 56 patients 39 improved (69.6%). Nine patients had no urinary incontinence; 5 out of these 9 patients improved (55.6%). These differences, however, are not statistically significant because the numbers are too small (X^2 test).

Extrapyramidal signs were present in 43 patients, 30 of which improved (69.8%). Thirteen patients had no extrapyramidal signs; 9 of these improved (69.2%). These differences are not statistically significant (X^2 test).

Thirty-nine patients had a total score of the triad > 15; 31 out of these 39 patients improved (79.5%). Seventeen patients had a total score of the triad < 15; 8 out of these 17 patients improved (47.1%). The differences between these two groups are statistically significant (X^2 test p=0.035).

Of the patients with idiopathic NPH, 20 had a total score of the triad > 15; 15 of them improved (75%). In this group 7 patients had a total score of the triad < 15; 2 out of 7 patients improved (28.6%). The differences between these two groups are nearly statistically significant (X^2 test p= 0.083).

Conclusion: more patients improved who had a total score of the triad > 15 than who had a score < 15.

In this study we use the term:

$$\text{progression rate} = \frac{\text{total score of the triad}}{\text{duration of illness in months}}$$

In Table XXIX a representation is given of the findings of progression rate and clinical outcome.

Conclusion: a larger number of patients with a progression rate ≥ 1.0 improved than with a progression rate < 1.0 (X^2 test p=0.013), which is a

statistically significant finding.

In 14 out of 27 patients with idiopathic NPH, gait disturbance was the first symptom. Nine out of 14 patients improved (64.3%). In 13 patients mentation disturbance was the first symptom; 8 out of these 13 patients improved (61.5%).

Conclusion: In this group of patients there is no correlation between improvement and type of first symptom.

1.5 Degree of clinical improvement

In Table XXX a survey is given of the pre- and postoperative mean clinical rates of the triad in 56 patients.

After surgery, each of the 39 improved patients had a reduction of > 75% of the pre-operative rating points of the triad.

As can be seen in Tables XXX and XXVI, pre-operative micturition disturbances in all 34 improved patients had disappeared after operation. In 25 out of 39 patients the gait disturbance had vanished and in 17 out of 39 patients the mentation disturbance had vanished after the operation.

When the responses of the signs to the shunting procedure are considered individually, micturition disturbance is most likely to improve to a large extent (100% of the patients); gait disturbance is the next most likely (64.1%) and dementia is the least likely (43.6% of the patients).

Before shunting 6 patients had epileptic seizures, after shunting 4 of them did not have seizures anymore. Three other patients developed epileptic seizures after the operation.

In accordance with the findings of Magnaes (1978) and of Børgesen and Gjerris (1982) we, too, found that clinical improvement was always apparent within 3 months after shunting. Further clinical improvement after this period was negligible.

1.6 Description of the patients who died

At the end of the study 12 out of 58 patients had died (20.7%). In the group of 39 improved patients 6 (15.4%) and in the group of 17 non-improved patients 4 (23.5%) had died at the end of the study. In Table XXXI a survey is given of these 10 patients, as well as of patients A and B, and their causes

of death.

As can be seen in Table XXXI, 7 patients with idiopathic NPH died and 5 patients with non-idiopathic NPH. So 7 out of 27 idiopathic NPH patients died (25.9%) versus 5 out of 31 non-idiopathic NPH patients (16.1%). The difference is not statistically significant (X^2 test).

Six patients died of the 19 patients aged 60-69 (31.6%) versus 5 of the 11 patients over 69 (45.5%). One patient died in the group of patients younger than 60 (3.6%).

2. RESULTS OF NEUROPSYCHOLOGICAL TESTING

In 37 patients pre- and postoperative psychological examinations were carried out. Many patients did not have this pre-operative investigation because their mental deterioration was so severe that the tests could not be performed.

In the 37 patients who were examined, the degree of cognitive reduction, relative to the estimated premorbid level, is rated on a 6 point-scale (1 = scarcely disturbed, 6 = most severely disturbed).

Improvement after surgery is defined as a reduction of at least one grade on this 6 point-scale.

Table XXXII summarizes the psychological findings before and after operation. As is shown in this table, 24 out of 37 patients (64.9%) showed improvements on the psychological rating scales after surgery.

As can be seen in Table XXXII there is a good correspondence between the postoperative psychological findings and the findings of the clinical rating scales (= clinical improvement). In 34 out of 37 patients (91.9%) the postoperative mental changes found in psychological examination agree with the findings of the clinical rating scales concerning improvements/non-improvements. However, the clinical rating scales test more functions than just mental deterioration only, such as gait disturbance and urinary incontinence. Improvement in the results of psychological testing was most frequently seen on the Wechsler Memory Scale concerning the functions of memorizing, orientation, mental control items, attention and spatioperceptual performance.

3. SURGICAL COMPLICATIONS AND SIDE-EFFECTS

Two patients (A and B) out of 58 patients died 2 weeks after surgery, which

established the surgical mortality rate at 3.4%.

In Table XXXIII a summary is given of the surgical complications and side effects in the other 56 patients.

Overall, 21 out of 56 patients had one or more (total 25) complications or side effects (37.5%). In 35 patients there were no complications (62.5%).

In Table XXXIV a survey is given of the different complications and side effects and their relationships with shunt type, aetiology, age and clinical outcome of surgery.

Subdural collections were diagnosed in 6 patients (10.7%) of whom 5 patients had no clinical signs and symptoms. Therefore in these patients we may consider these findings as side effects. One patient had symptomatic subdural collections which we consider a complication.

As can be seen in Table XXXIV there is no significant difference in percentage of complications between VA and VP shunts (X^2 test p=0.87).

There is no significant difference in percentage of complications between the idiopathic and non-idiopathic NPH group (X^2 test p=0.45), nor between the patients younger than 60 and 60 and up (X^2 test p=0.85), nor between the patients who improved and who did not improve after shunting.

4. RESULTS OF THE DOPPLER-LP TEST IN RESPECT OF CLINICAL OUTCOME OF SURGERY IN 56 PATIENTS

Of the 42 patients with a positive Doppler-LP test 38 patients improved (90.5%) and 4 patients did not improve (9.5%).

Of the 14 patients with a negative Doppler-LP test 1 patient improved (7.14%) and 13 did not (92.9%). The good prediction value of the Doppler-LP test (a positive Doppler-LP indicates there will be improvement and a negative Doppler-LP test indicates there will not be improvement) is 91.1% versus a false prediction value of 8.9%.

In Table XXXV a survey of these findings is given. There are no significant differences between the idiopathic and the non-idiopathic patients in the Doppler-LP test prediction values (X^2 test).

5. RESULTS OF ISOTOPE CISTERNOGRAPHY IN RESPECT OF CLINICAL OUTCOME OF SURGERY IN 50 PATIENTS (NOT INCLUDING PATIENTS A AND B)

In Table XXXVI a survey is given of the classification of cisternography findings in respect of clinical outcome of surgery.

In accordance with our definitions of positive and negative cisternography (Chapter VII.3), the cisternography (I^a, I^b, III^a) was positive in 36 patients and negative (IV) in 5 patients. In 9 patients the cisternograhy findings were not conclusive (II + III^b), which is indicated by ±. For conclusion purposes these non-conclusive cisternograms have been incorporated in the group of negative cisternography findings.

Table XXXVII gives a representation of these cisternography findings in respect of clinical outcome of surgery.

6. RESULTS OF EPIDURAL PRESSURE MONITORING IN RESPECT OF CLINICAL OUTCOME OF SURGERY IN 35 PATIENTS (WITHOUT PATIENTS A AND B)

In Table XXXVIII a survey is given of the results of epidural pressure monitoring in respect of clinical outcome of surgery.

7. COMPARISON OF EDPM, ISOTOPE CISTERNOGRAPHY AND DOPPLER-LP TEST IN RESPECT OF CLINICAL OUTCOME OF SURGERY

Thirty-one patients had all tests. As can be seen in Table XXXIX the good prediction values of EDPM, cisternography and Doppler-LP test in these patients are 71%, 51.6% and 87.1% respectively.

The differences between the prediction values of the Doppler-LP test and cisternography are statistically significant in favour of the Doppler-LP test (McNemar test $p < 0.05$).

The differences between the prediction values of Doppler-LP test and EDPM are not statistically significant (McNemar test $p > 0.05$). In Table XXXX a survey is given of the findings of all 3 tests.

When comparing the prediction value of the Doppler-LP test with the cisternography in 50 patients, we find that the Doppler-LP test has a statistically significant better prediction value than the cisternography (Table XXXXI).

When we compare the prediction value of the Doppler-LP test with EDPM, we do not find a significant difference in the prediction values of these two tests (Table XXXXII).

8. RESULTS OF CT SCANNING AFTER SURGERY

Of the 50 patients who had CT, 74% improved after shunting (not including patients A and B). Of the 37 patients who improved, 36 showed decrease of ventricular size after shunting. In the group of 13 patients who did not improve, 12 showed decrease of ventricular size too (Table XXII).

Conclusion: decrease of ventricular size after shunting did not show a relationship with the clinical response to shunting.

Twenty patients had pre-operative signs of periventricular oedema; 15 of them improved (75%) versus 22 improved patients out of 30 patients without periventricular oedema (73.3%).

A summary of the relationships between clinical outcome and other CT findings is given in Table XXXXIII.

Conclusion: the non-improved patients had a lower bifrontal cerebroventricular index than the improved patients (X^2 test $p=0.048$).

More patients with a Gado-index > 2.5 improved than patients with an index < 2.5 (X^2 test $p=0.023$).

The differences in percentages of improved patients who had and who did not have cortical atrophy are not statistically significant (X^2 test).

We did not find a significant difference in clinical outcome between the patients with enlargement of the fourth ventricle and those who did not have this enlargement.

9. RESULTS OF EEG EXAMINATION IN RESPECT OF CLINICAL OUTCOME OF SURGERY

In 51 patients a postoperative EEG was performed. Of the 36 patients who had clinically improved after surgery, 35 showed an improved EEG (97.2%), as can be seen in Table XXIII. Of the 15 patients without clinical improvement 13 showed an unimproved EEG (86.7%).

Conclusion: clinical improvement after shunting is highly correlated with EEG improvement and vice-versa.

In Table XXXXIV a survey is given of the relation between pre-operative

EEG findings and clinical outcome of surgery. As is shown in this table the pre-operative EEG pattern has little correlation with the clinical outcome and the EEG results of surgery.

10. RESULTS OF CSF ANALYSIS IN RESPECT OF CLINICAL OUTCOME OF SURGERY

As can be seen in Figures X, XI, XII and XIII there is no correlation between values of lumbar CSF total protein, lactate, ratio lactate/pyruvate, 5-HIAA and clincal outcome of surgery.

Not yet statistically significant more patients with HVA values < 350 nmol/l improved than patients with HVA values > 350 nmol/l (X^2 test $p=0.068$). However, two patients had had L-dopa medication which makes this finding unreliable.

Table XXVI. Clinical rating scales before shunting and at the end of the follow-up period

NO.	FOLLOW-UP PERIOD	GAIT	MENTATION	MICTURITION	EXTRAPYRAMIDAL SIGNS	BEHAVIOUR	ADL	CLINICAL IMPROVEMENT
1.	12 months (†)	8---10	8---9	7---7	3---3	1---1	4---5	-
2.	9 years	2---1	6---4	0---0	1---0	1---0	2---1	-
3.	9 years	4---2	2---0	5---0	0---0	1---0	1---0	+
4.	1 year	2---2	4---4	0---0	1---1	2---2	1---1	-
5.	3 months (†)	10---10	10---10	10---10	0---0	1---0	5---5	-
6.	7 years	10---0	9---2	10---0	0---0	0---0	5---0	+
7.	9 months (†)	5---5	2---2	3---1	0---0	1---1	3---3	-
8.	7 years	10---0	9---4	7---0	0---0	3---0	5---0	+
9.	5 years	4---4	9---9	10---10	3---3	2---2	5---5	-
10.	8 years	8---0	10---0	10---0	0---0	3---0	5---0	+
11.	7 years	2---2	2---2	1---1	1---1	1---1	0---0	-
12.	6½ years	10---0	10---0	10---0	2---0	3---0	5---0	+
13.	6 years	5---0	9---4	3---0	1---0	3---0	4---2	+
14.	6 years	4---1	4---1	0---0	0---0	3---0	2---0	+
15.	6 years	2---2	8---8	3---3	1---1	1---1	4---5	-
16.	1½ years (†)	8---0	8---2	7---0	1---0	2---0	4---0	+
17.	6 years	4---4	4---4	0---0	3---3	1---1	4---4	-
18.	2 years	10---10	10---10	10---10	0---0	0---0	5---5	-
19.	6 years	2---0	8---1	0---0	0---0	0---0	4---0	+
20.	6 years	4---0	2---0	0---0	0---0	0---0	1---0	+
21.	6 years	5---0	9---0	7---0	1---0	3---0	4---0	+
22.	6 years	2---0	4---1	0---0	1---0	1---0	2---0	+
23.	2½ years (†)	5---2	9---0	7---0	2---1	3---0	4---0	+
24.	5½ years	5---0	6---1	10---0	2---0	1---0	2---0	+
25.	9 months (†)	8---1	8---2	7---0	2---0	1---0	5---1	+
26.	5½ years	10---0	10---0	10---0	2---0	1---0	5---0	+
27.	5½ years	2---0	5---0	10---0	1---0	1---0	3---0	+
28.	5½ years	2---0	9---1	10---0	1---0	3---0	4---0	+
29.	5 years	2---0	9---0	7---0	1---0	2---0	4---0	+
30.	5 years	3---0	9---0	5---0	1---0	3---0	4---0	+
31.	5 years	10---0	10---0	10---0	2---0	0---0	5---0	+

Table XXVI. (continued)

NO.	FOLLOW-UP PERIOD	GAIT	MENTATION	MICTURITION	EXTRAPYRAMIDAL SIGNS	BEHAVIOUR	ADL	CLINICAL IMPROVEMENT
32.	6 months	4---2	4---4	0---0	2---1	3---1	4---4	-
33.	5 years	3---1	4---0	0---0	2---0	1---0	2---0	+
34.	16 months (†)	5---1	6---2	3---0	1---0	1---0	4---0	+
35.	4½ years	8---1	9---5	7---0	1---0	0---0	4---2	+
36.	4½ years	10---2	8---1	10---0	1---0	0---0	5---0	+
37.	4 years	4---0	5---2	7---0	1---0	1---0	3---1	+
38.	15 months	10---3	8---2	10---0	2---1	3---0	5---2	+
39.	22 months (†)	8---1	8---2	10---0	2---0	0---0	4---2	+
40.	4 years	5---0	9---0	10---0	0---0	0---0	5---0	+
41.	4 years	8---5	10---1	10---0	1---0	3---0	5---2	+
42.	3½ years	8---1	8---2	7---0	2---0	1---0	5---1	+
43.	1 year (†)	4---2	3---1	10---0	1---0	3---0	4---2	+
44.	3½ years	4---0	9---0	7---0	1---0	3---0	5---0	+
45.	2½ years	4---5	10---10	7---10	2---2	3---3	5---5	-
46.	2 years	4---0	9---2	7---0	1---0	1---0	4---0	+
47.	2 years	4---0	8---0	10---0	2---0	1---0	5---0	+
48.	2 years	4---0	8---2	5---0	2---0	3---0	4---1	+
49.	2 years	5---1	8---0	7---0	3---0	1---0	4---0	+
50.	2 years	10---10	10---10	10---10	2---2	0---0	5---5	-
51.	3 months (†)	8---8	10---8	10---10	2---2	3---0	5---5	-
52.	1 year	5---5	8---6	5---5	1---1	0---0	4---4	-
53.	1 year	3---3	6---6	5---5	3---2	2---2	3---3	-
54.	1 year	5---5	3---3	5---5	0---0	0---0	4---4	-
55.	1 year	8---2	6---1	5---0	2---0	3---0	4---0	+
56.	9 months	4---0	3---0	5---0	0---0	3---0	4---0	+

Table XXVII. Relation between duration of illness (in months) and clinical outcome

	1-3	4-11	12-23	24-35	36-up	N
All (n=56)	15	12	11	10	8	
Improved	12	10	9	5	3	39
Not improved	3	2	2	5	5	17
Idiopathic (n=27)	1	2	9	10	5	
Improved	1	1	7	5	3	17
Not improved	0	1	2	5	2	10

Table XXVIII. Relation between age of patients and clinical outcome

	< 20 yrs	20-29	40-49	50-59	60-69	70-up	N
All (n=56)							
Improved	4	3	3	11	10	8	39
Not improved	1	2	2	1	8	3	17
Idiopathic (n=27)							
Improved			1	3	6	7	17
Not improved			1		7	2	10

Table XXIX. Relation between progression rate and clinical outcome

	IMPROVED PATIENTS	NON-IMPROVED PATIENTS	N
Idiopathic (n=27)			
>1.0	8	2	10
<1.0	9	8	17
Not idiopathic (n=39)			
≧1.0	21	4	25
<1.0	1	3	4
All (n=56)			
≧1.0	29 (82.9%)	6	35
<1.0	10 (47.6%)	11	21

Table XXX. Mean clinical rates of the triad

		PRE-OPERATIVE	POSTOPERATIVE
GAIT	improved patients	5.76	0.61
	non-improved patients	5.17	5.17
MENTATION	improved patients	7.38	1.07
	non-improved patients	6.70	6.41
MICTURITION	improved patients	6.79	0
	non-improved patients	5.05	5.11

Table XXXI. Description of the patients who died

NO.	AGE	AETIOLOGY	DURATION OF FOLLOW-UP	DURATION OF IMPROVEMENT	CLINICAL IMPROVEMENT	CAUSE OF DEATH
1.	65	idiopathic	12 months	-	no	pulmonary embolism
5.	70	SAH	3 months	-	no	pulmonary embolism
7.	67	idiopathic	9 months	-	no	cardiac failure
16.	65	idiopathic	-	18 months	yes	cerebral metastases e.c.i.
23.	73	idiopathic	-	30 months	yes	paralysed ileus
25.	56	head surgery	-	9 months	yes	astrocytoma III
34.	62	head surgery	-	16 months	yes	astrocytoma III
39.	72	idiopathic	-	22 months	yes	cerebrovascular disease
43.	77	idiopathic	-	1 year	yes	dehydration
51.	75	idiopathic	3 months	-	no	epileptic seizures, cardiac failure
A.	65	SAH	-	-	nd	pneumonia, renal failure
B.	69	brain injury	-	-	nd	cardiovascular-respiratory insufficiency

nd: not determined

Table XXXII. Results of psychological testing

NO.	SCORE pre-operative	postoperative	IMPROVEMENT PSYCHOLOGICAL TESTING	CLINICAL IMPROVEMENT
2.	3	3	-	-
3.	3	0	+	+
4.	3	3	-	-
6.	5	2	+	+
7.	3	3	-	-
8.	5	2	+	+
11.	3	3	-	-
13.	5	3	+	+
14.	3	1	+	+
15.	5	5	-	-
16.	5	2	+	+
17.	3	3	-	-
19.	5	1	+	+
21.	5-6	2	+	+
22.	3	1	+	+
23.	5-6	2	+	+
24.	4	1	+	+
25.	5	3	+	+
27.	3	3	-	+
28.	5	1	+	+
29.	5-6	1	+	+
32.	3	3	-	-
33.	2	2	-	+
35.	5-6	3	+	+
36.	4	2	+	+
37.	3	2	+	+
39.	4	2	+	+
44.	5-6	1	+	+
46.	5	3	+	+
47.	5	1	+	+
48.	4	4	-	+
49.	4-5	1	+	+
52.	4	4	-	-
53.	3	3	-	-
54.	3	3	-	-
55.	4	1	+	+
56.	3	1	+	+

Table XXXIII. Surgical complications and side-effects in 56 patients

NO.	SHUNT TYPE	SURGICAL COMPLICATIONS AND SIDE-EFFECTS
3.	VA	bilateral subdural collections without clinical signs and symptoms, ventricular collapse
4.	VA	revision because of curling ov the cardial shunt in the jugular vein; after 1 year sepsis and removal of the shunt
8.	VA	revision of the ventricular shunt because of malfunction
9.	VA	revision of the ventricular shunt, bilateral subdural collections without clinical signs and symptoms
12.	VA	revision of the ventricular shunt because of malfunction
13.	VA	revision of the ventricular shunt because of malfunction
16.	VA	revision because of dysconnection in the neck
23.	VA	bilateral subdural collections without clinical signs and symptoms
27.	VA	bilateral subdural collections without clinical signs and symptoms
28.	VA	epileptic seizures
31.	VP	dysconnection of the peritoneal shunt
32.	VA	sepsis, removal of the shunt after 6 months
33.	VA	bilateral subdural collections with ventricular collapse and symptoms: ligation of the shunt: high pressure shunt
36.	VA	revision (2x) of ventricular and cardial shunt
37.	VA	revision of the cardial shunt, epileptic seizures
38.	VA	subdural collections without clinical signs and symptoms
39.	VA	revision of the ventricular shunt because of malfunction
43.	VP	revision of the abdominal shunt because of malfunction
47.	VP	revision of the abdominal shunt because of malfunction
51.	VP	epileptic seizures
52.	VP	partial dysfunction ventricular shunt: low pressure shunt

VA: ventriculoatrial

VP: ventriculoperitoneal

Table XXXIV. Surgical complications and side-effects in 56 patients

SHUNT TYPE	COMPLICATIONS (NUMBER OF PATIENTS) NONE	SHUNT MAL-FUNCTION	INFECTION	SUBDURAL COLLECTIONS	EPILEPTIC SEIZURES
VA (42)	26 (61.9%)	9 (33.3%)	2 (4.8%)	6 (14.3%)	2 (4.8%)
VP (14)	9 (64.3%)	4 (28.6%)	0 (0%)	0 (0%)	1 (7.1%)
Total (56)	35 (62.5%)	13 (23.2%)	2 (3.6%)	6 (10.7%)	3 (5.4%)
		IN 21 PATIENTS (37.5%)			

	COMPLICATIONS IN NUMBER OF PATIENTS ABSENT	PRESENT	N
Non-idiopathic	20	9	29
Idiopathic	15	12	27
Patients <60	19	8	27
Patients ≥60	16	13	29
Patients improved	23	16	39
Patients not improved	12	5	17

Table XXXV. Results Doppler-LP test-clinical outcome

	DOPPLER-LP TEST positive	negative	PREDICTION VALUE good	false
All (n=56)				
Improved	38 (90.5%)	1		
Not improved	4	13 (92.9%)		
			91.1%	8.9%
Idiopathic (n=27)				
Improved	16 (94.1%)	1		
Not improved	1	9 (90%)		
			92.6%	7.4%
Non-idiopathic (n=29)				
Improved	22 (88%)	0		
Not improved	3	4 (100%)		
			89.7%	10.3%

Table XXXVI. Classification cisternography-clinical outcome

CLASSIFICATION	N=50	IMPROVED	NOT IMPROVED
I^a	19	14 (73.7%)	5 (26.3%)
I^b	14	9 (64%)	5 (36%)
II	8	4 (50%)	4 (50%)
III^a	3	3 (100%)	0 (0%)
III^b	1	0 (0%)	1 (100%)
IV	5	4 (80%)	1 (20%)

Table XXXVII. Results cisternography-clinical outcome

	CISTERNOGRAPHY positive	negative	±	PREDICTION VALUE good	false
All (n=50)					
Improved	26 (72.2%)	4	4		
Not improved	10	1	5		
		42.9%		64%	36%
Idiopathic (n=27)					
Improved	12	3	2		
Not improved	7	0	3		
				55.6%	44.4%
Non-idiopathic (n=23)					
Improved	14	1	2		
Not improved	3	1	2		
				73.9%	26.1%

Table XXXVIII. Results epidural pressure monitoring-clinical outcome

	EDPM		PREDICTION VALUE	
	positive	negative	good	false
All (n=35)				
Improved	18 (69.2%)	2		
Not improved	8	7 (77.8%)		
			71.4%	28.6%
Idiopathic (n=17)				
Improved	8	1		
Not improved	4	4		
			70.6%	29.4%
Non-idiopathic (n=18)				
Improved	10	1		
Not improved	4	3		
			72.2%	27.8%

Table XXXIX. Comparison of epidural pressure monitoring, cisternography and Doppler-LP test in respect of clinical outcome after surgery

NO.	EDPM	CISTERNOGRAPHY	DOPPLER-LP TEST	CLINICAL IMPROVEMENT
2.	-	-	+	-
4.	+	+	-	-
5.	-	+	-	-
7.	+	-	-	-
9.	-	+	-	-
10.	+	+	+	+
11.	+	-	-	-
13.	+	-	+	+
15.	+	+	-	-
16.	+	+	+	+
17.	+	-	-	-
21.	+	-	+	+
22.	+	+	+	+
24.	+	-	+	+
26.	+	+	+	+
32.	-	+	+	-
33.	+	-	+	+
34.	+	-	+	+
35.	+	+	+	+
36.	+	+	+	+
39.	+	+	-	+
44.	+	+	+	+
46.	+	-	+	+
48.	-	-	+	+
49.	+	+	+	+
50.	+	-	-	-
51.	-	+	+	-
52.	+	-	-	-
53.	-	+	-	-
54.	-	+	-	-
56.	-	+	+	+
		GOOD PREDICTION VALUE:		
	22/31=71%	16/31=51.6%	27/31=87.1%	

Table XXXX. Comparison of the 3 tests and clinical outcome

DOPPLER-LP TEST N=56	NOT IMPROVED	IMPROVED	CISTERNOGRAPHY N=50	NOT IMPROVED	IMPROVED	EDPM N=35	NOT IMPROVED	IMPROVED
negative	13=92.9%	1	negative	1 } 6=42.9%	4 } 8	negative	7=77.8%	2
			±	5 }	4 }			
positive	4	38=90.5%	positive	10	26=72.2%	positive	8	18=69.2%
			np	(1)	(5)	np	(2)	(19)
good prediction value	91.1%			64.0%			71.4%	

np: not performed

Table XXXXI. Comparison Doppler-LP test and cisternography (n=50)

DOPPLER-LP TEST	NOT IMPROVED CISTERNOGRAPHY		IMPROVED CISTERNOGRAPHY		DOPPLER-LP TEST	PREDICTION VALUE CISTERNOGRAPHY	
	negative	positive	negative	positive		good	false
negative	5	8	0	1	good	30	16
positive	1	2	8	25	false	2	2
McNemar test	p=0.039		p=0.039			p=0.0013	

Table XXXXII. Comparison Doppler-LP test and EDPM (n=35)

DOPPLER-LP TEST	NOT IMPROVED EDPM			IMPROVED EDPM			DOPPLER-LP TEST	PREDICTION VALUE EDPM		
	negative	positive	np	negative	positive	np		good	false	np
negative	4	7	2	0	1	0	good	21	9	21
positive	3	1	0	2	17	19	false	4	1	0
McNemar test	$p > 0.10$			$p > 0.10$				$p > 0.10$		

np: not performed

Table XXXXIII. CT findings - clinical outcome

	IMPROVED	NOT IMPROVED	N
Third ventricle enlarged	25=71.4%	10	35
Third and fourth ventricle enlarged	11=84.6%	2	13
Both ventricles not enlarged	1	1	2
Cortical atrophy			
absent	25=83.3%	5	30
slight	4 } 60%	3 } 40%	7
moderate-severe	8 }	5 }	13
Bifrontal cerebroventricular index			
0.38-0.44	7	7	14
0.45-0.49	11	3	14
≧ 0.50	19	3	22
Index Gado			
< 2.5	13=56.5%	10	23
> 2.5	24=88.9%	3	27
CT not performed	2	4	6

Table XXXXIV. Relation between pre-operative EEG findings and clinical outcome

PRE-OPERATIVE EEG (N=54)		CLINICAL IMPROVEMENT yes	no
slowing present	(n=40)	27 (67.5%)	13
slowing not present	(n=14)	10 (71.4%)	4
focal changes present	(n=33)	25 (75.8%)	8
focal changes not present	(n=21)	12 (57.1%)	9
general dysrhythmia present	(n=25)	17 (68%)	8
general dysrhythmia not present	(n=29)	20 (69%)	9

Chapter IX

CONCLUSIONS AND DISCUSSION

In this chapter a survey of the main conclusions and results of our study is given.

Although NPH is not a common condition, its significance within the spectrum of dementias is greater than its relative prevalence because of its potential curability.

The aims of this study are to put an end to the clinical confusion of arguments for indication of shunting and to find a better selection criterion for shunting therapy in patients with NPH.

In this thesis, 58 patients with NPH who underwent a shunting procedure are studied and compared with a group of 30 patients with internal hydrocephalus who did not undergo shunting.

NPH in this study is defined as a clinical syndrome of progressing dementia, gait disturbances with or without urinary incontinence, associated with ventricular enlargement and normal lumbar CSF pressure ($\leq$ 20 cmH_2O). Internal hydrocephalus on CT scan is defined as ventricular dilatation with a cerebroventricular index of the bifrontal diameter $\geq$0.40 in adults (Hahn and Rim 1976).

1. DESCRIPTION OF THE PRE-OPERATIVE FINDINGS

1.1 Clinical signs and symptoms

In our group of 58 patients, 46.6% had idiopathic NPH. The patients with idiopathic NPH were older than the patients with non-idiopathic NPH (Wilcoxon test, $p \leq 0.001$). Thirty out of 58 patients were 60 years old and up (51.7%) and 11 out of 58 patients were 70 years old and up (19%).

Looking at the age when the 27 patients developed idiopathic NPH, it is evident that the diagnosis was especially made in patients who were 59 or older which is in accordance with the study of Katzman (1977). Patients with idiopathic NPH had a longer duration of illness before shunting than patients with non-idiopathic NPH (Wilcoxon test $p \leq 0.001$). Of the 27 patients with idiopathic NPH, 22 patients had concomitant signs of hypertension and/or diabetes mellitus, arteriosclerosis or cerebrovascular disease (81.5%) which had not been diagnosed as the cause for NPH. In 14 persons, gait disturbance was the symptom first observed and in 13 persons mental disturbance was the first symptom.

All 58 patients had signs of gait and mentation disturbances (according to

our definition of NPH) and 49 patients had urinary incontinence too.

1.2 CT scanning (n=52)

Dilatation of the third ventricle was seen in 96% of the patients; dilatation of the fourth ventricle in 26.9%. Periventricular oedema was noted in 40.4% of the patients. Jacobs et al. (1978) found in 34% of their patients periventricular oedema. Cortical atrophy was present in 38.5% of our patients; slight atrophy in 7 patients (13.5%), moderate-severe atrophy in 13 patients (25%).

1.3 EEG (n=56)

In our group of 56 patients only 2 patients had normal EEG recordings. Focal changes (local delta-activity in the frontotemporal region) were seen in 60.7% of the patients. In most of the patients (76.5%) it was found on the left side. These findings were comparable in the idiopathic and non-idiopathic group. These left-sided focal findings as found in our patients have not been described in NPH cases in the literature before.

Focal theta- and delta-activity is commonly reported over the temporal regions, particularly the left, in persons older than 60 (Silverman et al. 1955, Otomo and Tsubaki 1966). This focal slowing is usually assumed to be due to asymptomatic local alterations in blood flow and oxygen uptake (Sulg and Ingvar 1967, Meyer et al. 1967, Kooi et al. 1964), although the left-sided accentuation has not been explained so far. In our patients it may also be a sign of local vascular insufficiency in the dominant hemisphere. Diffuse slowing was demonstrated in 75% of the patients and also in 74% of the patients with idiopathic NPH. Generalized dysrhythmias were found in 48% in both the total group and in the group of idiopathic NPH.

Our findings that the EEG is disturbed in most of the patients with NPH is in agreement with the studies of Greenberg et al. (1977) and Magnaes (1978).

1.4 SSEP (n=10)

SSEP studies in NPH patients are not mentioned in the literature. In 9 out of

10 patients we found severe disturbances in the late components of the SSEP. The SSEP in all 10 patients was normal up to the P_{100}; the P_{100} itself was delayed or absent in 5 out of 10 patients. These findings are in agreement with the presence of a grey matter disturbance in NPH.

1.5 CSF analysis (n=48)

All patients had lactate values > 1580 μmol/l (P_{50}) and 39 out of 48 patients (81.3%) had lactate values > 1818 μmol/l (P_{90}). This is compatible with the existence of cerebral ischaemia in NPH. Twenty-one out of 53 patients (39.6%) had total protein values > 423 mg/l (P_{90}); all of them with signs of transudation in CSF analysis. This finding was especially surprising in the idiopathic NPH group. It is not described in the literature.

2. SURGICAL RESULTS

2.1 Clinical signs and symptoms and clinical outcome of surgery

Two patients died 2 weeks after surgery, which amounts to a surgical mortality of 3.4%.

Of the 56 patients who were followed after surgey for at least 3 months 69.6% improved. Of the idiopathic group, 63% improved versus 75.9% in the non-idiopathic group. This difference is statistically not significant (X^2 test). More patients with a duration of illness shorter than 24 months improved than patients with a duration of illness of 24 months and longer (X^2 test p=0.012). This is in agreement with the findings of Petersen et al. (1985) in their group of 45 idiopathic NPH patients.

In our study, there was no relation between age of the patients and clinical outcome after operation. This is in agreement with the findings of Greenberg et al. (1977) and Børgesen and Gjerris (1982).

In our study there was no statistically significant relation between surgical outcome and aetiology and no relation between surgical outcome and combination of symptoms; i.e. the presence of the complete clinical triad versus the incomplete triad. However, our number of patients might have been too small to find differences statistically significant. But when we look at the degree of clinical deficit concerning the clinical triad score, we see that

it is statistically significant that more patients with a triad score > 15 improve after surgery than patients with a score < 15 (X^2 test p=0.035). In the total group of patients, more patients with a progression rate $\geq$ 1.0 improved than patients with a progression rate < 1.0 (X^2 test p=0.013).

After shunting, micturition disturbances disappeared in all the patients that improved. Gait disturbances vanished in 25 out of 39 patients that improved (64.1%), and mentation disturbances disappeared in 17 patients (43.6%). So shunting had the most effect upon micturition and gait disturbances in our NPH patients.

In the idiopathic NPH patients, there was no relation between improvement and type of the symptom first observed.

In accordance with the studies of Magnaes (1978) and Børgesen and Gjerris (1982), we too found that clinical improvement was always evident within 3 months after shunting, and changes one year after the operation do not differ from those after 3 months. When we consider the long-term follow-up, we find that 12 out of 58 patients (20.7%) had died at the end of the study. In the group of 39 patients that improved, 6 patients (15.4%) had died because of other concomitant diseases. Five out of these 6 patients were older than 60 years.

2.2 Surgical complications and side-effects

With respect to the surgical mortality of 3.4% in our study, the 37.5% overall complication rate and the percentages of complications of subdural collections, infection, shunt malfunction etc., these were all within the limits described in the literature.

There is no statistically significant difference in percentages of complications between the ventriculoatrial and the ventriculoperitoneal drain (X^2 test p=0.87). We found no differences in percentages of complications between the idiopathic and the non-idiopathic patients, between the patients who improved and who did not improve after operation and also no difference between the patients younger than 60 and patients of 60 years and older (X^2 test $p > 0.40$).

2.3 CT scanning

We found that on CT decrease of ventricular size itself bore no relation to the clinical response (improvement) to shunting. This is in agreement with the findings of Shenkin et al. (1975), Jacobs et al. (1978) and Børgesen and Gjerris (1982). Enlargement of the third ventricle versus enlargement of the third and fourth ventricles bore statistically no significant relation to clinical outcome after surgery, nor did the presence or absence of cortical atrophy (X^2 test $p > 0.1$).

We agree with Laws and Mokri (1977) and Petersen et al. (1985) that atrophy is not a significant indication of poor response.

In accordance with Petersen et al. (1985), periventricular oedema did not show a significant correlation with the clinical outcome after shunting in our group. In our study, the degree of ventricular dilatation before operation correlated positively with favourable surgical response. The patients who did not improve had a lower pre-operative CT index than the patients who improved (X^2 test $p=0.048$). We also found that significantly more patients with a Gado index > 2.5 improved than patients with a Gado index < 2.5 (X^2 test $p=0.023$).

2.4 EEG

In our study clinical improvement after surgery was highly correlated with EEG improvement.

However, the pre-operative EEG pattern had little correlation with the clinical and EEG outcome after surgery. We agree with the literature findings that the EEG is not helpful in selecting patients with NPH for surgery (Wood et al. 1974, Stein and Langfitt 1974, Guidetti and Gagliardi 1972).

2.5 Neuropsychological testing

In 37 patients pre- and postoperative psychological investigation was done. Twenty-four out of 37 patients (64.9%) improved on the psychological rating scales (for cognitive functions) after surgery.

There was a good correspondence between the postoperative psychological findings and the findings of the clinical rating scales in 34 out of 37

patients (91.9%).

2.6 CSF analysis

No relationship could be established between values of lactate, ratio lactate/pyruvate, total protein, 5-HIAA and the clinical outcome of surgery.

Not yet statistically significant more patients with normal values of HVA improved than patients with HVA values >350 μmol/l (X^2 test p=0.068).

2.7 Isotope cisternography

In 52 patients, isotope cisternography was performed. In accordance with the literature we made a classification of the findings and found in 5 patients a normal (negative) cisternogram. In 22 patients the cisternographic pattern was representative for NPH and a mixed form, suspective for NPH was found in 14 patients (positive cisternography). In 9 patients a pattern not conclusive for NPH was noted. In the groups of patients with negative and non-conclusive patterns, 57.1% of the patients improved after operation versus 72.2% in the positive pattern group. For all the patients, the cisternography had a correct prediction value of 64% and an incorrect prediction value of 36%.

We agree with the literature studies that isotope cisternography is not a reliable guide in selecting patients with NPH for surgery.

2.8 Epidural pressure monitoring

In 35 patients epidural pressure monitoring was performed. We preferred the epidural method to the ventricular method because of the advantage of less risks of infection, catheter blockages and leakage of CSF. The ICP recording was classified as abnormal (positive) if, peakpressure exceeded 15 mmHg during a period of at least 10 minutes, especially during sleep overnight (Tans 1979) or if the peakpressure was twice or more the baseline pressure (Belloni et al. 1976).

The disadvantage of this technique is that it is an invasive method and in patients (with dementia) who lack cooperation it is not feasible. By contrast with the radioisotope cisternography, it was not difficult to discriminate a

positive from a negative test. In our patients, 26 had a positive and 9 patients had a negative test. The correct prediction value in this group of 35 patients was 71.4% and the incorrect prediction value 28.6%. These findings were not significantly better than the percentages of the isotope cisternography (McNemar test $p > 0.10$).

2.9 Doppler-LP test

A new technique introduced in this thesis is the Doppler-LP test. Studies of CBF in patients with NPH are described by Raichle et al. (1974) and Mathew et al. (1975) as being of interest in selecting patients for shunting. When the increases of CBF, especially in the area of the carotid system, were 15% or more after CSF removal by means of LP, then the patients improved after shunting. The technique used for these CBF studies was the intra-arterial radioisotope method of Lassen and Ingvar (1961). However, this technique has severe limitations. It is invasive and requires a certain amount of patient cooperation. The complexity of the apparatus and the relatively high amount of radioactivity make this technique not suitable for bedside use and in general neurologic practice. These reports and findings prompted us to study patients with NPH by means of the simpler and innocuous ultrasonic Doppler technique that could give an indication of changes in CBF. Jonkman et al. (1978) studied the relationship between bloodflow velocity in the common carotid artery and CBF in man. They found a linear relationship between changes in CBF and the mid-diastolic blood flow velocity in the common carotid artery.

Jonkman et al. (1978) confirmed the hypothesis that Doppler-shift measurements can be used as a simple technique for monitoring changes in CBF.

The results of our technique have to be considered as semi-quantitative only, but the necessary equipment is simple and can be used at the bedside. The procedure requires only a gentle and stable hand of the investigator, but almost no patient cooperation. Only in restless patients or patients with tachycardia, with cardiac irregularity, the test is not reliable.

It is very easy to study rapid changes of CBF with this technique and the Doppler-LP test mimics the situation occuring in shunt therapy.

The Doppler technique was applied directly before and 5 minutes after lowering CSFP to zero by removal of 30-40 ml CSF by means of lumbar puncture. The test was performed in 25 control patients without hydrocephalus,

aged 13-71 years. None of these patients showed an increase of 2 mm or more in the D_1 and D_2 values after LP. This is in agreement with the fact that in normal persons there is a CSFP-CBF autoregulation which prevents CBF from altering when (lumbar) CSFP is lowered.

The Doppler-LP test was performed with success in 88 patients with internal hydrocephalus. Of this group 58 patients underwent a shunting procedure with the diagnosis of NPH.

Of the 30 patients who underwent no operation, 27 patients did not show an increase of 2 mm or more of the D_1 and D_2 values and in these patients the Doppler-LP test was described as negative. In 3 patients the Doppler-LP was positive; i.e. these patients showed an increase of 2 mm or more of the D_1 and D_2 values after LP. Two out of these 3 patients showed progression of signs and symptoms of the clinical triad of NPH. In the group of 27 patients with internal hydrocephalus and negative Doppler-LP test, 10 patients had a final diagnosis of (arrested) NPH, with a stable course or improvement for several years. This suggests that the decision not to shunt these patients was justified. We suppose that in these patients there was an intact CSFP-CBF autoregulation which was pointed out with our Doppler-LP test. We suppose that this intact CSFP-CBF autoregulation prevents progression of signs and symptoms of the NPH syndrome in these patients.

The findings in these 10 patients can be compared with the description of Hughes et al. (1978), who evaluated the natural history of 12 unoperated idiopathic NPH patients, and with the findings of Bachman (1977). Our findings too, emphasize the equally varied course that patients can experience without a shunt. In the group of 27 patients with a negative Doppler-LP test, 16 had another final diagnosis such as M. Alzheimer, multi-infarct dementia etc. One patient underwent a shunt operation elsewhere without improvement.

Of the 58 patients with NPH who underwent shunting 44 patients had a positive Doppler-LP test and 14 patients had a negative Doppler-LP test. Two patients with a positive Doppler-LP test died two weeks after surgery. Therefore results of the Doppler-LP test in respect of clinical outcome after surgery could be studied in 56 patients.

Of the 14 patients with a negative Doppler-LP test, 13 patients did not improve (92.6) and 1 patient improved (7.1%).

Of the 42 patients with a positive Doppler-LP test, 90.5% improved and 9.5% did not improve. The percentages of the idiopathic patients did not differ, in a statistically significant way, from the non-idiopathic patients (X^2 test). In the total group of 56 patients, the Doppler-LP test had a cor-

rect prediction value of 91.1% and an incorrect prediction value of 8.9%. The percentages of the idiopathic patients did not differ, in a statistically significant way, from the non-idiopathic patients (X^2 test).

The differences of prediction values with the radioisotope cisternography were statistically significant in favour of the Doppler-LP test (McNemar test p=0.0013), but the difference of prediction value was not statistically significant with respect to the EDPM (McNemar test).

So the Doppler-LP test is a better test than the isotope cisternography in predicting the clinical outcome of NPH patients after surgery, as well in the idiopathic as in the non-idiopathic group.

Because the EDPM has not a better prediction value than the Doppler-LP test, we prefer the Doppler-LP test because of its simple technique without discomfort for the patients. The EDPM calls for neurosurgical intervention and asks much cooperation from the patients during 48 hours, which is not feasible in the more demented patients.

In conclusion: patients suspected of having a NPH syndrome have to undergo CT scan for detecting (the degree of) internal hydrocephalus.

The method most preferable for selecting patients for shunt operation is in our opinion, the Doppler-LP test. When the Doppler-LP test is positive the patient has a change of approx. 90% to improve after surgery; when the Doppler-LP test is negative this chance is approximately 10%.

Our findings with respect to the Doppler-LP test support the theory that there may be a relationship between blood and CSF circulation in the pathogenesis of NPH.

We know that ventricular enlargement is not the only factor in producing the signs and symptoms in NPH. Jacobs et al. (1978) found in 33% of the improved patients after shunting that the ventricles remained enlarged. Salmon and Timperman (1971) demonstrated that shunting in some patients resulted in significant improvement without any noticeable change in ventricular size. Yet, an increase in CBF was demonstrated in these patients. The hypothesis has been submitted that the clinical improvement is the result of increasing CBF. This increase in blood flow to non-functioning or damaged neurons permits them to regain function. In patients with NPH, the normal CSFP-CBF autoregulation impairs and when CSF is removed CBF increases, particularly in the frontal regions. Also Mathew et al. (1975) and Meyer et al. (1977) found that in the majority of cases the upper frontal and post-central areas showed maximal increase in regional CBF after lowering CSFP. This is in the area of the anterior cerebral artery of the carotid system. With the Doppler-LP test

it is the carotid system which is investigated.

Greitz (1969) postulated that the circulatory disturbances might be responsible for serious but reversible symptoms. Also Van Crevel (1972) suggests a relationship between blood and CSF circulation in the pathogenesis of NPH with his theory of the external "hydraulic press effect".

Also descriptions of autopsy cases suggest a causal role of cerebrovascular insufficiency and hypertensive cerebrovascular disease (Earnest et al. 1974, Coblentz et al. 1978, Vessal et al. 1974, Stein and Langfitt 1974).

The vascular damage could reduce tissue bulk and tensile strength, allowing the ventricles to enlarge under the stress of the increased intraventricular CSF pulse pressure of hypertensive vascular disease.

This may be the reason that we found a strikingly high percentage (81.5%) of patients with signs and symptoms of vascular disease in our patients with idiopathic NPH.

In this context, our EEG findings of local delta-activity found in the left frontotemporal region could be interpreted as a sign of vascular insufficiency in the dominant hemisphere. Our findings give arguments for the vascular theory and for the theory that in some patients with NPH the normal CSFP-CBF autoregulation is impaired or defective. When we can detect the patients with this defect, as seems to be possible with the Doppler-LP test, than we can select these patients with a view of successful surgery.

Chapter X

SUMMARY/SAMENVATTING

Hakim and Adams (1965) are generally credited with the discovery of NPH as a treatable syndrome. They stressed the importance of the clinical triad of dementia, gait disturbance and urinary incontinence in diagnosing NPH. The NPH syndrome or Hakim-Adams syndrome is a clinical entity associated with ventricular enlargement, without any clinical evidence of increased intracranial pressure. A normal CSF pressure is found (on isolated observation) when lumbar puncture is performed. The syndrome of NPH can follow meningitis, SAH etc; conditions which might lead to some sort of CSF blockage. Most cases, however, have no obvious preceding cause. Such cases are defined as idiopathic NPH.

In Chapter II a review of the literature concerning general aspects of the NPH syndrome is given. Since 1965 many reports have appeared referring to the very mixed results from shunting in patients with NPH. As can be seen in Chapter II, the diagnostic procedures commonly used to establish the diagnosis of NPH often fail to predict which patients will benefit from shunting. Each test, for example radioisotope cisternography, ICPM, spinal infusion test, has its advantages and yet each test has turned out to be deficient in some respect. Although an unbalance between production and absorption of CSF has been accepted to be an important factor in the pathophysiology of NPH, the precise mechanisms behind the development of NPH are as yet uncertain. Several theories that have been put forward are described in Chapter III. In this chapter (III) a summary is included about the circulation of CSF and the functions of the so-called third circulation. Studies of CBF in patients with NPH seem to point out that there is a defect in CBF autoregulation. It is postulated that the circulatory disturbance might be responsible for the (reversible) symptoms. We know that ventricular dilatation is not the only factor in producing the signs and symptoms in NPH. As described in Chapter III, CBF is reduced in NPH but increased after shunting procedure or after lowering the CSFP by means of lumbar puncture.

These literature studies prompted us to measure the blood flow velocity in the common carotid artery through Doppler sonography before and after CSF removal by means of lumbar puncture.

The Doppler-LP test, introduced as a new technique in this thesis, is a simple and innocuous test; it is described in Chapter IV. The value of this test in predicting the clinical outcome in patients with NPH after CSF shunt-

ing is studied in this thesis. The aims of our study are:

1. to put an end to the clinical uncertainties as to when shunting is indicated in patients with NPH;
2. to find a reliable indicator for shunting;
3. to evaluate the clinical applicability of the Doppler-LP test;
4. to evaluate the Doppler-LP test in a non-hydrocephalic population (Chapter V);
5. to study the predictive value of the Doppler-LP test in a group of 58 NPH patients that underwent shunting (Chapter VIII);
6. it was not the direct aim of the study to examine the predictive value of the Doppler-LP test in a group of (30) patients with internal hydrocephalus who did not undergo shunting (Chapter VI).

In Chapter VII a description is given of the preoperative findings in 58 patients who underwent shunting.

In Chapter VIII the results of the Doppler-LP test in 58 patients who underwent shunting are compared with results of other tests such as isotope cisternography, CT scanning, EDPM and with the clinical signs and symptoms.

In Chapter IX a survey is given of the main results and conclusions of our study. Some of the conclusions are summarized below.

- More patients with a duration of illness < 24 months improved than patients with a duration of illness of ≥ 24 months.
- There was no relation between age of a patient and improvement after surgery.
- More patients with a clinical triad score > 15 (most diseased) improved after shunting than patients with a score < 15.
- More patients with a progression rate ≥ 1.0 improved than patients with a progression rate < 1.0.
- In most patients the EEG showed disturbances (diffuse slowing, focal delta-activity). Clinical improvement after shunting is closely related to EEG improvement. However, the pre-operative EEG pattern has little correlation with the clinical and EEG outcome after shunting.
- In 9 out of 10 patients we found disturbances in the so-called late components of the SSEP.
- The degree of ventricular dilatation seen on CT before surgery correlated positively with a favourable surgical response.
- Cortical atrophy on CT has no significant value in predicting the clinical outcome after surgery.

- Enlargement of the third ventricle versus enlargement of the third and fourth ventricle had no statistically significant relation with the clinical outcome after surgery.
- As well in the idiopathic as in the non-idiopathic group the Doppler-LP test appeared to be a better test than isotope cisternography in predicting the clinical outcome after surgery.
- Because the EDPM did not have a better prediction value than the Doppler-LP test, we prefer the Doppler-LP test because of its simpler technique with hardly any discomfort for the patient.

Detection of internal hydrocephalus and the degree of ventricular dilatation requires patients suspected of having a NPH syndrome to undergo CT scanning. The method most preferable for selecting patients for shunting is, in our opinion, the Doppler-LP test. If the Doppler-LP test is positive, the patient has a chance of approx. 90% to improve after surgery; if the Doppler-LP test is negative, this chance is approx. 10%.

Our findings support the theory that there is a relationship between blood and CSF circulation in the pathogenesis of NPH. In some patients with NPH the normal CSFP-CBF autoregulation is disturbed or has a defect. If we can detect patients with this defect, as seems to be possible with the Doppler-LP test, then we can select these patients for successful shunting.

De eer van de ontdekking van NPH als een behandelbaar syndroom wordt in het algemeen toegekend aan Hakim en Adams (1965). Om de diagnose NPH te kunnen stellen legden zij de nadruk op het belang van het aanwezig zijn van het zogenaamde trias: mentale deterioratie, loopstoornissen en incontinentie voor urine.

Het syndroom van NPH, ook wel genoemd het syndroom van Hakim en Adams, is een omschreven klinisch beeld in combinatie met hydrocephalus internus zonder klinische tekenen van verhoogde intracraniële druk. Bij lumbale punctie wordt een normale liquordruk gevonden. Het syndroom NPH kan optreden na meningitis, subarachnoïdale bloeding etc.; ziektebeelden, die kunnen leiden tot een stoornis in de liquorcirculatie. Vaak echter is er geen voorafgaande ziekteoorzaak bekend en dan wordt gesproken van idiopathische NPH.

In hoofdstuk II wordt een literatuuroverzicht gegeven betreffende diverse aspecten van het syndroom NPH. Er zijn sinds 1965 vele mededelingen verschenen over de zeer wisselende resultaten van shuntoperaties bij patiënten met NPH. In hoofdstuk II wordt beschreven, dat de diagnostische methoden, gebruikt om de diagnose te stellen, vaak falen in het voorspellen welke patiënten baat zullen hebben bij een operatie. Iedere test, zoals bijvoorbeeld radioisotopen cisternografie, intracraniële drukmeting en spinale infusietest, heeft zijn eigen waarde maar ook zijn tekortkoming.

Alhoewel algemeen aanvaard wordt, dat het bestaan van een wanverhouding tussen productie en resorptie van liquor een belangrijke factor is in de pathofysiologie van NPH, zijn er toch nog vele factoren onbekend. De vele theorieën, die hieromtrent zijn gevormd, worden beschreven in hoofdstuk III.

In dit hoofdstuk wordt ook een samenvatting gegeven betreffende de liquorcirculatie, alsmede van de functies van de zogenaamde derde circulatie.

Cerebrale blood-flow studies, verricht bij patiënten met NPH, hebben doen veronderstellen, dat er een stoornis bestaat in de autoregulatie van de CBF. Er wordt aangenomen, dat deze stoornissen in de bloedcirculatie verantwoordelijk zouden kunnen zijn voor de (reversibele) klinische verschijnselen en symptomen.

Bekend is, dat ventrikelverwijding op zich niet de enige factor kan zijn in het veroorzaken van de klinische verschijnselen. In hoofdstuk III wordt beschreven dat het bekend is, dat de CBF verlaagd is bij patiënten met NPH en dat er na shuntoperatie of na verlaging van de liquordruk middels lumbale

punctie een toename optreedt van de CBF.

Deze literatuurstudies deden ons besluiten om de bloedstroomsnelheden in de arteria carotis communis te gaan meten via de methode van de Doppler sonografie (haematotachografie) zowel voor als na afname van liquor via lumbale punctie.

De "Doppler-LP test" wordt in deze studie geïntroduceerd als een nieuwe methode. De uitvoering van deze eenvoudige en onschadelijke test wordt beschreven in hoofdstuk IV. In dit proefschrift wordt de voorspellende waarde van deze test ten aanzien van de klinische resultaten na shuntoperatie bestudeerd.

De doelstellingen van onze studie zijn:

1. het beëindigen van de klinische onduidelijkheden ten aanzien van indicatiestellingen voor operatie bij NPH;
2. het vinden van een betrouwbare indicatiemethode voor shuntoperatie;
3. het onderzoeken van de klinische toepasbaarheid van de Doppler-LP test;
4. onderzoek met de Doppler-LP test bij een groep patienten zonder hydrocephalus (hoofdstuk V);
5. het onderzoeken van de voorspellende waarde van de Doppler-LP test in een groep van 58 patienten met NPH die geopereerd werden (hoofdstuk VIII);
6. het was niet de directe bedoeling van deze studie om de voorspellende waarde van de Doppler-LP test na te gaan in een groep van 30 patienten met hydrocephalus internus, en die niet werden geopereerd (hoofdstuk VI).

In hoofdstuk VII worden de pre-operatieve bevindingen beschreven bij de groep van 58 patienten die werden geopereerd.

In hoofdstuk VIII worden de resultaten van de Doppler-LP test bij de 58 geopereerde patienten vergeleken met de resultaten van de andere testen, zoals de isotopen cisternografie, CT-scan en epidurale drukmeting, en met de klinische verschijnselen.

In hoofdstuk IX wordt een overzicht gegeven van de belangrijke resultaten en conclusies van onze studie. Enkele van deze conclusies worden hier samengevat.

- Er zijn meer patienten verbeterd met een korte ziekteduur (< 24 maanden) dan patienten met een langere ziekteduur ($\geq$ 24 maanden).
- Er was geen relatie tussen leeftijd van de patient en resultaat van de operatie.
- Er zijn meer patienten verbeterd met een klinische scoring van het trias > 15 (het meest aangedaan) dan patienten met een scoring < 15.

- Er zijn meer patienten verbeterd met een klinische progressie ratio $\geq 1,0$ dan patienten met een ratio $< 1,0$.
- Bij de meeste patienten vertoonde het EEG afwijkingen zoals diffuse verlangzaming en locale trage haardactiviteit. De klinische verbetering na de operatie gaat in hoge mate samen met EEG-verbetering. Echter het pre-operatieve EEG-tracée heeft weinig relatie met de klinische- en EEG-verbetering na de operatie.
- Bij 9 van de 10 patienten vertoonde de SSEP afwijkingen in de zogenaamde late componenten.
- De mate van ventrikelverwijding, zichtbaar op de CT-scan voor operatie, was positief gecorreleerd met een goed klinisch resultaat na de operatie.
- Corticale atrofie zichtbaar op de CT-scan heeft geen voorspellende waarde ten aanzien van het operatieresultaat.
- Verwijding van de 3e ventrikel ten opzichte van verwijding van de 3e en de 4e ventrikel heeft geen significante relatie met het operatieresultaat.
- In onze studie heeft de Doppler-LP test een betere voorspellende waarde voor het operatieresultaat dan de isotopen cisternografie. Dit geldt zowel voor de patienten met een idiopathische NPH als voor de groep met een bekende oorzaak voor NPH.
- Omdat de epidurale drukmeting niet beter voorspelt dan de Doppler-LP test, geven wij de voorkeur aan de Doppler-LP test vanwege het feit, dat deze laatste eenvoudiger uitvoerbaar is met minder ongemak voor de patient.

Voor het vaststellen van een hydrocephalus internus en de mate van ventrikelverwijding dienen patienten met verdenking op het bestaan van NPH een CT-scan te ondergaan. Wij zijn van mening, dat de Doppler-LP test als methode om patienten te selecteren voor operatie de voorkeur heeft. Als de Doppler-LP test positief is, heeft de patient een kans van ongeveer 90% om te verbeteren na de operatie. Is de Doppler-LP test negatief, dan is deze kans ongeveer 10%.

Onze bevindingen staven de theorie, dat er een relatie bestaat tussen bloed- en liquorcirculatie ten aanzien van de pathogenese van NPH. Bij sommige patienten met NPH is de normale "CSFP-CBF" autoregulatie gestoord. Wanneer wij in staat zijn patienten met deze stoornis op te sporen, dan kunnen wij deze patienten selecteren voor een succesvolle operatie. Dit lijkt mogelijk te zijn door middel van de Doppler-LP test.

CASE HISTORIES

Patient 1

This 65-year-old woman had had gait difficulty over a period of 1½ years. Since 1 year there had also been an increasing intellectual decay and urinary incontinence. There was slowing of mental and physical activity, depressive feelings and impairment of recent and later on also of remote memory with disorientation as to date and place. Because of her masklike face, bradykinesia and rigidity, the diagnosis Morbus Parkinson had been made. Treatment with L-dopa, however, was without result. In the past she had been treated with Reserpine because of hypertension.

On admission she had asymmetrical paraparesis of combined pyramidal and extrapyramidal character that was more marked on the left side. She needed support in walking and standing; the gait was spastic, ataxic and short-stepped.

The PEG showed a severe enlargement of all ventricles including the third and fourth; no air filling was seen on the convexity. The RIHSA cisternogram displayed a ventricular stasis of isotope up to 48 h without activity on the convexity. The EEG revealed a 9-10 Hz alpha activity with focal slowing in both temporal-basal regions L > R.

Because of the clinical diagnosis of idiopathic NPH, a medium ventriculoatrial shunt was placed. However, after having placed the functioning shunt, the illness had a progressive course after operation, which can be seen in the clinical rating scales 11 months after shunting. She became completely bedridden and died 12 months after the operation because of pulmonary embolism.

Patient 2

This 45-year-old man had a 4 year history of memory loss, dizziness, headache, fatigue and compulsive weeping. These symptoms developed slowly after a period of influenza, fever and right-sided hemiparesis with motor aphasia.

On examination there was still a slight hemiparesis with staggering gait and two-sided Babinski's signs. He had disturbance in memorizing and fluctuations of consciousness, he was disoriented as to date. RR 160/100 mmHg. There was mild obesity and rigidity; no urinary incontinence.

PEG showed a moderate internal hydrocephalus with enlargement of lateral and third ventricles, a little frontal cortical atrophy L > R and without cortical air filling elsewhere. Carotid angiography showed signs of diffuse arteriosclerosis. The RIHSA cisternogram showed ventricular filling of isotope up to 24 hours, but also some activity on the convexity at this moment. The EEG revealed slight slowing of the dominant 8-8½ Hz rhythm without focal abnormalities. A 48 hour epidural pressure monitoring showed no pressure waves.

A medium ventriculoatrial drain was placed. Three months after shunting he was free from headache; his gait was less staggering and his behaviour better. However, EEG and psychological testing showed no improvement 1½ years after surgery. His condition was stable for the next 9 years.

Patient 3

This 25-year-old woman with neurofibromatosis had been regressing mentally from the age of sixteen; she had slowing of mental and physical activity, reduced spontaneity, depressive feelings and indifference towards her environment. There was obesity because of excessive eating. Onset of menstruation had been induced by medication when she was 16. For one year she had com-

plained of instability in walking, urinary incontinence and headache. She also had had generalized epileptic seizures during the last year.

On admission we saw a very obese and apathetic young woman with multiple café au lait spots. There was slight disturbance in memorizing and recent memory. The gait was broad-based with signs of spastic paraparesis L > R with Babinski's signs and ankle clonus. There was also truncal ataxia. There were no signs of increased intracranial pressure.

CT and PEG showed a severe communicating internal hydrocephalus without cortical air filling on PEG, but there were two cysts next to the mesencephalon on the left side. The RIHSA cisternogram showed ventricular filling and stasis of isotop up to 48 hours. Carotid and vertebral angiography showed no abnormalities. The EEG disclosed slight slowing of the dominant rhythm with non-specific paroxysmal transient discharges.

Because of the diagnosis NPH, a medium ventriculoatrial drain was placed. Three months after operation the patient had clearly improved; she was active and she no longer suffered from headaches or fits. The gait had improved. One year after shunting she was free from signs and symptoms; she had lost her overweight. The EEG had improved with an increased alpha frequency of 0.5 Hz. Psychological testing also showed remarkable improvement. One year after shunting the CT scan showed collapse of the ventricles and signs of bilateral collections. The CT scan 2 years and 3½ years after surgery showed the same slit-ventricles but vanished subdural collections. Until now the patient is in an excellent condition.

Patient 4

Patient is a 52-year-old man with a long history of psychiatric illness. In 1954 he had undergone a frontal topectomy because of episodic attacks of phobic anxiety with aggression, depressive and paranoid feeling which did not diminish after electroconvulsive therapy. After topectomy he had been well for several years. However, since about 4 years the same psychiatric features had compelled to turn to psychotherapy without success. Moreover, he complained of headaches, memory disturbance and instability in walking. He had grand mal seizures for approximately 4 years that had begun as psychomotor attacks. There was no urinary incontinence.

On neurological examination a slight spastic paraparesis with extensor plantar responses was found. There were remarkable disturbances in recent and remote memory. He had a masklike face.

The PEG showed an obvious internal hydrocephalus with dilatation especially of the frontal horns and third ventricle; there was air filling in the frontal region, nowhere else cortical air filling was seen. The RIHSA showed ventricular stasis of isotope up to 48 hours. The EEG demonstrated 9-10 Hz alpha activity and too much theta-delta activity in the frontal and frontotemporal regions. Continuous extradural pressure monitoring for 96 hours showed pressure waves.

A medium ventriculoatrial drain was placed, but 6 weeks later drain revision had to be done because of thrombophlebitis of the right arm and curling of the cardiac drain in the jugular vein. A Raymundi peritoneal drain was placed. However, 1 year later the drain had to be removed because of sepsis with signs of meningitis. In the meantime however, despite a functioning drain, there was no improvement in the patient's condition as can be seen in the clinical rating scales. EEG and psychological investigation 6 months after shunting showed no improvement.

Patient 5

This 70-year-old man was admitted to our hospital with clinical signs of a subarachnoid bleeding, which was confirmed by means of lumbar puncture. He was treated with aminocaproic acid. Two months after the bleeding, mentation deteriorated to nonsensical talk and afterwards to stupor. He was unable to walk and had complete urinary incontinence. Carotid angiography demonstrated diffuse arteriosclerosis, no aneurysm was seen; however, lateral bowing of the thalamostriate vein with elevation and straightening of the pericallosal artery indicated ventricular enlargement.

The RIHSA cisternogram showed ventricular stasis of isotope up to 48 hours. A 48 hour continuous extradural pressure monitoring showed no pressure waves. After lumbar puncture mentation seemed to be better.

A ventriculoatrial drain was placed. However, despite functioning drain, the following 3 months after shunting gave no improvement. Three months after sugery the patient died of cardiac failure and pulmonary embolism.

Patient 6

This 57-year-old woman had had a subarachnoid bleeding with left-sided hemiparesis. Seventeen days after the bleeding, two aneurysms were clipped; one of the right middle cerebral artery and one of the anterior communicating artery. CT at this moment showed a normal ventricular system. Two weeks after this operation the patient's condition regressed. She got confused, became unable to walk, had urinary incontinence and her level of consciousness lowered.

CT scan now showed dilatation of the lateral, third and fourth ventricles (frontal horn index 0.45). RIHSA cisternography showed normal CSF circultion. The EEG showed diffuse slowing of 6-7 Hz activity with slow wave activity in the right temporal region.

Four weeks after operation and $6\frac{1}{2}$ weeks after the bleeding a medium ventriculoatrial drain was placed. Her condition improved well as can be seen in the clinical rating scales. The EEG showed 8-9 Hz activity and also psychological testing clearly showed improvement. CT scan showed decrease of ventricular size (index 0.33).

Patient 7

Patient is a 67-year-old man with progressing gait difficulty and signs of mental regression for 2 years. His family had observed reduced spontaneity and depressive behaviour and later on also impairment of memorizing. No prior history of head injury, meningitis or cerebral haemorrhage was known. Sometimes he had urinary incontinence.

On neurological examination we saw a mildly obese man, RR 180/100; irregular pulse. He walked with a pair of crutches; there was an obvious spastic paraparesis; R > L with Babinski's signs. He had slowing of mental activity and impairment of recent memory.

CT scan showed internal hydrocephalus with dilatation of the lateral and third ventricles (index 0.41), without cortical atrophy. The RIHSA cisternogram demonstrated ventricular stasis of isotope up to 24 hours with some parasagittal activity at that moment. The EEG showed diffuse slowing with alpha activities of $8\frac{1}{2}$-9 Hz. A 48 hour continuous extradural pressure monitoring showed elevated ICP (26-28 cmH_2O) waves.

Because of the diagnosis, idiopathic NPH, a medium ventriculoatrial drain was placed. CT scan after shunting showed reduction of ventricular size

(index 0.34), but clinically no improvement was seen 3 and 6 months after operation. The alpha activity in the EEG had decreased by ½ Hz and psychological examination and clinical rating scales showed no significant change. Nine months after operation the patient died because of cardiac failure.

Patient 8

Patient is a 49-year-old woman with neurofibromatosis who 6 weeks before shunting had had a subarachnoid haemorrhage from an angiodysplasia of the left anterior and middle cerebral artery. She had a right-sided hemiplegia with hemianopsia and aphasia. After clinical improvement, her condition regressed 4 weeks after the bleeding. Her level of consciousness lowered; she became paranoid and aggressive. Besides the aphasia there was delirium, confusion and disorientation as to time, place and person.

In addition to signs of a left parasellar bleeding the CT showed a progressive internal hydrocephalus with dilatation of the lateral and third ventricles L > R; frontal horn index 0.53. Carotid angiography showed a persistent, primitive left trigeminal artery and angiodysplasia of the middle and anterior cerebral artery on the left side. RIHSA cisternography was not performed.

A medium ventriculoatrial drain was placed 6 weeks after the haemorrhage. A dramatic imporvement was seen within 2 days. Two weeks later, however, her condition regressed again. Control of the drain showed dysfunction (CT index 0.57) and revision of the ventricular drain was done. Now the clinical condition improved well, the hemiparesis disappeared, consciousness, mentation and behaviour improved. One month after surgery the CT showed normal ventricular size of lateral and third ventricles. Clinical state and psychological testing clearly showed improvement 3 months after surgery. There was a stable clinical condition during the next 7 years.

Patient 9

This 66-year-old man had had Parkinsonian features for 8 years without response to medication. During the last 6 months the symptoms presented themselves in a progressing rate and with rapidly increasing dementia and urinary incontinence. No prior cause had been found.

On examination we saw a disorientated and paranoid man with confusion, nonsensical talk and urinary incontinence. There was strong rigidity and akinesia with buccopharyngeal dyskinesia and extrapyramidal tremors of the hands. He had a stiff-legged shuffling gait with retropulsion and a history of falling.

CT showed a severe dilatation of the lateral and third ventricles and moderate cortical atrophy (index 0.55). RIHSA cisternography demonstrated ventricular stasis of isotope up to 48 hours but also parasagittal activity. A 48 hour continuous extradural pressure monitoring showed no pressure waves. The EEG showed diffuse slowing (alpha: 7-8 Hz) with FIRDA. Psychological testing was not feasible.

A medium ventriculoatrial drain was placed; 3 weeks later a revision was done because of dysfunction of the ventricular end. In the meantime, a further dilatation of the ventricular system had been made visible on CT scan. After the revision operation, control CT showed a clear decrease in ventricular size (index 0.42), but it also showed signs of bilateral subdural collections. The patient's clinical condition, however, dit not change, nor did the EEG over a follow-up period of >5 years.

Patient 10

This 60-year-old man, who had been treated with anticoagulants because of cardiac infarction 9 years ago, had a subarachnoid haemorrhage from an arteriovenous malformation in the area of the right pericallosal artery. After surgical intervention his condition regressed, he developed signs of akinetic mutism, urinary incontinence and gait difficulty.

Control angiography showed signs of severe ventricular dilatation. The RIHSA cisternography showed ventricular stasis of isotope up to 24 hours. A 48 hour epidural pressure monitoring showed pressure waves.

One month after surgery and 3 months after the subarachnoid bleeding, a medium ventriculoatrial drain was placed. After shunting, the patient improved dramatically and 12 months after shunting, no signs or symptoms could be noted.

Patient 11

Patient is a 20-year-old woman who had enjoyed good health until 17 years old when she was hit by a motorcar and suffered from a slight injury. She had to keep her bed at home for some days without neurological examination. From this time she complained of headache, disturbance of concentration and learning disabilities so that she had to leave secondary modern school. She had depressive feelings and slowing of mental and psychical activity with reduced spontaneity. Sometimes she had generalized epileptic seizures. Since the head injury there existed secondary amenorrhoea and obesity. Sometimes she had urinary incontinence and a staggering gait.

On admission we saw an indolent obese woman with a masklike face, impairment of recent memory and staggering gait. Plantar reflexes were extensor. Laboratory tests showed a normal T4 and GTT and a slight hyperprolactinaemia.

The PEG demonstrated obvious internal hydrocephalus with dilatation of the lateral ventricles with normal third and fourth ventricle and no cortical air passage. The RIHSA cisternogram showed ventricular filling and stasis of isotope up to 24 hours but also parasagittal activity. A 48 hour extradural pressure monitoring showed pressure waves. CT scan showed moderate enlargement of the lateral ventricles (index 0.43) and slight enlargement of the third ventricle. The EEG was characterized by a diffuse slowing R > L with signs of irritative paroxysmal generalization.

Because of the diagnosis NPH, a medium ventriculoatrial drain was placed. Patient's condition did not change postoperatively, despite good functioning of the drain and decrease of ventricular size on CT (index 0.39) after 18 months and (0.35) after 2 years. The EEG was more disturbed and because of epileptic seizures she was given carbamazepine. Psychological examination after 6 months and 2 years showed no improvement.

Patient 12

This 8-year-old girl had a severe head injury with concussion, basal skull fractures, left parietal fracture and artificial mechanical respiration had been performed for some weeks. Three months after the head injury the patient was aggressive, she had coma vigil and spastic tetraplegia.

PEG showed an enormous internal hydrocephalus with dilatation of the lateral, third and fourth ventricles without cortical air filling. CT demonstrated frontal horn index 0.61 and signs of frontal concussion. The EEG showed diffuse slowing with 1-4 Hz activities. The RIHSA cisternography showed ventricular stasis of isotope up to 48 hours.

After a medium ventriculoatrial drain (with revision) had been placed, consciousness improved first, later on also behaviour. Two months after shunting there was very great improvement with spastic atactic gait. The EEG showed faster activities with 4-7 Hz; after 9 months 8-9 Hz activities. One year after surgery there was only slight disturbance in memorizing and concentration; gait and behaviour were normal. CT showed reduction of ventricular size with frontal horn index 0.44. During the next years more improvement was seen as is pointed out in the rating scales.

Patient 13

This 67-year-old woman had a 6-year history of loss of memory, dizziness and headache. Since 1 year there had been a rapidly increasing dementia with gait disturbance and sometimes urinary incontinence. No prior history of brain injury, meningitis or cerebrovascular disease was known.

On admission we saw a mildly obese woman with mild rigidity and apathy. She was disorientated as to place, time and person, there were confabulations and confusion. She was paranoid and aggressive. Her gait was broad-based, short-stepped with a tendency to falling backwards, she needed to touch objects in walking. Next to the frontal ataxia there was dressing apraxia. Patient had pseudobulbar reflexes and Babinski's signs. RR 160/100.

CT showed dilatation of the lateral and third ventricles with frontal horn index 0.45. There was some insular cortical atrophy. Carotid angiography demonstrated signs of diffuse arteriosclerosis. The RIHSA cisternography showed a normal CSF circulation. A 48 hour continuous epidural pressure monitoring showed pressure waves. The EEG showed diffuse slowing (7 Hz) with a maximum in the right temporal region (2-3 Hz).

A medium ventriculoatrial drain was placed. After the shunting (with revision), the gait and behaviour disturbance improved clearly; 3 months later there was still memory disturbance which did not change during the follow-up period of 6 years. Postoperatively the EEG improved; the background activity was 1 Hz faster. CT scan showed decrease in ventricular size (index 0.39). Also psychological examination showed improvement.

Patient 14

This 20-year-old man had had a brain injury with coma for 4 weeks two years before shunting. The last six months there had been regression in mental functions with disturbances in memorizing, apathy, aggressive feelings. He had gait disturbance, headache, but no urinary incontinence.

On admission we saw an apathetic man with paraparesis R > L and Babinki's signs. He had loss of recent and remote memory.

CT scan showed dilatation of the lateral, third and fourth ventricles; frontal horn index 0.58. The RIHSA cisternogram demonstrated ventricular stasis of isotope up to 48 hours. The EEG showed diffuse slowing (alpha 8-8½ Hz) with irritative activities in both temporal regions R > L.

A medium ventriculoatrial drain was placed. Four weeks after surgery his behaviour and memorizing improved, his gait was normal but he was unable to walk tandem. EEG and psychological testing also showed improvement. CT revealed some reduction in ventricular size (index 0.51). The postoperative EEG showed 9½ Hz activities. His condition was stable during the following 6 years.

Patient 15

This 48-year-old woman had been admitted to our hospital because of dementia progressing for two years. In the beginning change in mentation was observed first; it was of insidious onset and had begun with apathy, indifference towards her environment and depressive feelings. She started to whisper and became forgetful. She had impairment of recent and later on also of remote memory and became disorientated as to time and place. Sometimes she suffered from headaches. She had a staggering gait and sometimes urinary incontinence. She had always been in good health and there was no prior history of headtrauma or meningitis. At the onset of the presenting symptoms hypertension had been found and was treated with antihypertensiva.

We saw a mildly obese woman with a masklike face; she was very indolent. She was disorientated as to time, place and person; she perseverated, there were severe disturbances in recent and remote memory. The staggering gait was broad-based, reflexes of the legs were brisk with Babinski's signs. She had signs of ideational apraxia.

The CT scan showed a moderate internal hydrocephalus (frontal horn index 0.41) with normal fourth ventricle, but enlarged third ventricle; the cortical sulci of the left Sylvian fissura were widened. Carotid angiography showed no abnormalities. The RIHSA cisternogram displayed ventricular filling and stasis of isotope after 24 h and after 49 h with a little activity parasagittally. The EEG showed a 9-10 Hz alpha activity and theta-delta activity in the left temporal-basal region. A 48-hour epidural pressure monitoring showed pressure waves.

The clinical diagnosis, idiopathic NPH, was made and a ventriculoatrial shunt was placed. After shunting, no improvement occurred although the size of the ventricular system had diminished 6 months later (index 0.36). The EEG and psychological examination showed no changes, nor did the clinical ratings resp. 3, 6 and 20 months after surgery.

Patient 16

This 65-year-old woman had had progressing dementia for 18 months and since 4 months also gait difficulty and urinary incontinence. Sometimes she suffered from headaches. She had depressive and paranoid feelings. There was no prior history of craniocerebral trauma, meningitis or (cerebro)vascular disease. Several maternal family members had suffered from presenile dementia syndromes e.c.i.

On admission we saw a mildly obese woman with a pale and masklike face, strong bradykinesia and apathy. She was disorientated as to date, place and person and she confabulated. There was severe memory disturbance and also daily urinary incontinence. She had difficulties in initiating moving and walking. Her broad-based gait was short-stepped with spastic-ataxic aspects and with a tendency to falling backwards. Plantar responses were extensor, snout- and jaw reflexes brisk.

Carotid angiography revealed signs of diffuse arteriosclerosis both intra- and extracranial. The EEG was characterized by a diffuse slowing and by periodic groups of delta waves in the left frontotemporal region. CT showed severe dilatation of the third and lateral ventricles (frontal horn index 0.53). The RIHSA cisternogram demonstrated ventricular filling and stasis of isotope up to 48 hours. A 48 hour extradural pressure monitoring revealed episodic A and B pressure waves.

Because of the diagnosis, idiopathic NPH, a medium ventriculoatrial drain was placed. The next day a remarkable improvement in patient's condition could be observed. During the following days and weeks she improved in mental

competence, initiative and gait, urinary incontinence ceased. Two weeks later swelling of the neck due to accumulation of cerebrospinal fluid was seen because of disconnection between valve and cardial shunt and a drain revision had to be done. Control CT showed a clear decrease in ventricular size (frontal horn index 0.40) and also the EEG had improved. Repeated neuropsychological testing showed significant cognitive improvement. Her very good clinical condition, as can be seen in the rating scales, continued for 18 months after shunting. From that time she developed nausea, vomiting, headaches and lowering consciousness. Further investigation showed a functioning shunt, but CT and arteriography revealed signs of multiple metastases in the left occipital and basal ganglia regions. Later an obstruction in the foramen of Monro developed. The primary site of the tumours had not been found and the patient died 20 months after shunting. Autopsy was not allowed.

Patient 17

This 63-year-old man had had progressing instability in walking with a history of falling for 2½ years; the last 3 months there had been stiffness of the legs. For about six months his family had observed forgetfulness, problems with reading, emotional lability and clumsiness, especially in dressing. There was no urinary incontinence. No prior history of brain injury, meningitis or cerebrovascular disease was known.

On examination we saw a man with Parkinsonian features, such as rigidity, akinesia and tremors of the hands. The gait was spastic and atactic and there was difficulty in initiating movements. There were pyramidal and extrapyramidal signs in the legs. There was slight disturbance in recent memory and moderate dyslexia and dressing apraxia.

CT scan showed dilatation of the lateral and third ventricles (index 0.43) and slight cortical atrophy of the left Sylvian fissure. Carotid angiography demonstrated signs of diffuse arteriosclerosis. The EEG showed diffuse slowing and focal slowing in the left frontotemporal region. RIHSA cisternogram showed ventricular stasis of isotope up to 24 hours with some parasagittal activity. A 48 hour continuous extradural pressure monitoring showed pressure waves.

Because of the diagnosis, idiopathic NPH, a ventriculoatrial drain was placed. No clinical improvement could be found 3 and 12 months after shunting despite a visible reduction in ventricular size (index 0.40) 8 months after surgery. EEG and psychological testing remained also unchanged.

Patient 18

This 19-year-old man had had a severe brain injury with concussion 3 months before shunting.

CT showed progressing dilatation of the lateral and third ventricles (frontal horn index 0.52). PEG showed ventricular dilatation with blocking of the peripheral cortical air passage. The EEG demonstrated diffuse slowing with 1-2 Hz and sometimes 5 Hz activities. A 48 hour continuous epidural pressure monitoring showed pressure waves.

A medium ventriculoatrial drain was placed in a patient with coma vigil and spastic tetraparesis. One month after shunting, CT showed frontal horn index 0.47. Nevertheless, no apparent improvement was seen in his clinical condition during the following 24 months.

Patient 19

This 13-year-old girl had had a severe brain injury with concussion and basal skull fractures six months before shunting. Four months after the brain injury she was admitted to our hospital, because of headaches, mental retardation and a staggering gait.

On examination we saw a mildly obese, apathetic girl with strong disturbances in memorizing; she had loss of recent and remote memory, was disorientated as to date and place, she confabulated. Her gait was broad-based with slight paraparesis of pyramidal origin. There was no urinary incontinence.

PEG showed ventricular dilatation of the whole ventricular system with blocking of peripheral air filling. CT demonstrated progressing dilatation of the third and lateral ventricles; frontal horn index 0.50. There was periventricular oedema. The RIHSA cisternogram showed ventricular stasis of isotope up to 55 hours. The EEG showed diffuse slowing with focal delta activity in the right parietotemporal region.

A medium ventriculoatrial drain was placed. Six months after shunting, there was good improvement in her clinical condition, especially in her mental functions, and it was also found by psychological testing. The EEG showed 8-9 Hz activities. CT showed a decrease in ventricular size (frontal horn index 0.39).

Patient 20

This 14-year-old girl had congenital right-sided spastic hemiparesis and epilepsy caused by cerebral birth injury. Since about six months this girl had had learning disabilities at school because of disturbances in concentration and memorizing. She had also complained of headache and progressing staggering gait with a history of falling.

On admission we saw a young woman with spastic right-sided hemiparesis and hemiatrophy. She was apathetic, had loss of recent memory, disturbances in concentration and memorizing. The gait was broad-based spastic and ataxic with circumduction of the right leg, but there was also spasticity of the left leg. Reflexes were exaggerated with two-sided plantar extensor reflexes. There was no urinary incontinence.

CT revealed severe dilatation of the third and fourth ventricle and giant asymmetric dilatation of the lateral ventricles (index 0.56) with signs of a left frontotemporal porencephalic cyst. The EEG showed diffuse irritative components and local slow-wave activity with polyspike waves in the left temporal region. A 48 hour continuous extradural pressure monitoring showed pressure waves.

Because of the diagnosis, porencephalic cyst with NPH, a ventriculoperitoneal drain was placed. After shunting, a rapid improvement was seen in mentation and gait. Control EEG had improved, too, with 9-9½ Hz activities and without irritative components. CT demonstrated a remarkable decrease of the ventricular size (index 0.46).

Patient 21

This 57-year-old woman had had, 4 months before shunting, a severe brain injury with a right-sided frontotemporal subdural haematoma which had been treated by washing out. After this operation the patient had recovered. Two months later, however, she had regressed mentally, she got forgetful and was suffering from gait disturbance and urinary incontinence.

On admission we saw a mildly obese woman who confabulated, she was con-

fused and disorientated as to time, place and person. She needed to touch objects when walking. There was mild rigidity and akinesia; sometimes she was aggressive. The gait was spastic and broad-based with Babinski's signs.

CT demonstrated progressing dilatation of both lateral and the fourth ventricles (index 0.53) and periventricular oedema. The RIHSA cisternogram showed ventricular filling and stasis of isotope up to 24 hours and some parasagittal activity. A 48 hour continuous extradural pressure monitoring revealed pressure waves. The EEG demonstrated diffuse slowing with focal delta and irritative activity in the left temporal region.

A medium ventriculoatrial drain was placed. Three weeks later remarkable improvement was obtained, as was seen in the clinical rating scales and by psychological testing. Control CT showed reduction in ventricular size (frontal horn index 0.47). The EEG showed 8½-9 Hz activities 3 months after the operation.

Patient 22

This 63-year-old woman had had slowing of mental and physical activity, depressive feelings and indifference towards her environment for 1 year. The last six months she had complained of forgetfulness, gait disturbance and ptosis of the left eye. No history of brain injury, meningitis or cerebrovascular disease was known.

On admission we saw an obese, depressive woman with mild akinesia, rigidity and masklike face. She had a staggering gait without a tendency to falling. She was disorientated as to date and had a strong failure in recent memory. There was ptosis of the left eye; no urinary incontinence. She had a mild diabetes mellitus and hypertension.

CT showed dilatation of both lateral, third and fourth ventricles (index 0.45) and slight cortical atrophy. Carotid angiography revealed no abnormalities. The RIHSA cisternogram showed ventricular filling and stasis of isotope up to 48 hours. A 48 hour continuous epidural pressure monitoring demonstrated pressure waves. The EEG showed diffuse irritative components with non-specific paroxysmal activities.

Because of the diagnosis, idiopathic NPH, a medium ventriculoatrial drain was placed. Immediately after shunting, the ptosis of the left eye diminished. Some weeks later the gait was normal, the patient was more active, less forgetful and recent memory was only abnormal by history. Control CT showed reduction in ventricular size (index 0.42). The EEG showed less irritative components with 9 Hz activities. Psychological examination after 6 months showed improvement too.

Patient 23

This 73-year-old man had a two-year history of gait disturbance and loss of memory. The last six months he had to touch objects when walking. There had been daily urinary incontinence. The last months he had regressed mentally and had shown confusion and nonsensical talk. He was paranoid and aggressive. There had been a prior history of a TIA, hypertension and a mild diabetes mellitus 5 years ago.

On examination we saw a very lean and apathetic man with slight delirium and confusion. Sometimes he was paranoid and aggressive. There was difficulty in initiating moving and walking. His broad-based gait was short-stepped with a tendency to falling backwards; he needed to touch objects in walking. Snout- and jaw reflexes were brisk; he had compulsive weeping. There was strong rigidity and akinesia. RR 150/100.

CT showed moderate dilatation of both lateral and third ventricles (frontal horn index 0.41), but also moderate diffuse cortical atrophy. RIHSA cisternogram showed ventricular filling of isotope up to 24 hours. The EEG demonstrated diffuse slowing with focal delta activity and irritative disturbances in the left frontotemporal region.

Three months after a medium ventriculoatrial drain was placed, clear improvement was seen as to intellectual, behavioural and motor functions; urinary incontinence ceased. Control CT 2 weeks and 3 months after surgery showed a normal ventricular size (index 0.29); however, bilateral subdural collections were visible. Because of the patient's excellent condition no measures were taken. Control EEG and psychological testing revealed clear improvement too. His excellent condition continued for $2\frac{1}{2}$ years after shunting. Then he had a fall resulting in a fracture of the hip. A total hip prothesis had been placed and he received a pacemaker because of Stokes-Adams attacks. Some months later he died after an operation for paralysed ileus.

Patient 24

This 53-year-old man had had progressing gait difficulty for 18 months and loss of memory and daily urinary incontinence for 1 year. No prior history of brain injury, meningitis or (cerebro)vascular disease was known.

On admission we saw a patient with a masklike face and broad-based gait. He had to touch objects in walking, there was retropulsion and tendency to falling backwards. Strong rigidity and akinesia were present. He was disorientated as to date and place, there was strong disturbance in recent and remote memory. He had depressive feelings. Plantar reflexes were extensor.

CT showed severe dilatation of both lateral ventricles (frontal horn index 0.50) with normal third and fourth ventricles. The In^{111} DTPA cisternogram showed no ventricular filling of isotope and no signs indicating NPH. A 48 hour continuous extradural pressure monitoring revealed pressure waves. The EEG demonstrated diffuse irritative activities with alpha frequency 9-10/sec.

Because of the diagnosis, idiopathic NPH, a medium ventriculoatrial drain was placed. Some days after surgery a dramatic improvement was seen in mentation, gait and extrapyramidal signs. Urinary incontinence ceased. Control CT two weeks after shunting showed slit-ventricles. The EEG demonstrated 11-12/sec alpha activity and less irritative activities. One year after shunting the patient was in a very good condition as was seen in the clinical rating scales and as was demonstrated by psychological testing.

Patient 25

This 56-year-old woman had undergone partial resection and post-radiation for a left frontal astrocytoma grade III, 21 months before shunting. Her condition had been satisfactory for 18 months, whereafter she got forgetful, accompanied by slowing of mental and physical activity, gait disturbance and urinary incontinence.

On admission we saw a mildly obese woman with strong rigidity and akinesia. There was difficulty in initiating moving and walking. She needed support in walking, the gait was broad-based, short-stepped with a tendency to falling backwards. Reflexes were aggravated and she had Babinski's signs. There was a strong loss of recent memory and she was disorientated as to place and date.

CT showed progressive dilatation of the third and both lateral ventricles (frontal horn index 0.47) without signs of tumour. RIHSA cisternography was not performed. The EEG showed diffuse slowing and delta and irritative activ-

ities in the left frontal and frontotemporal region. A 48 hour continuous extradural pressure monitoring revealed pressure waves.

Because of the diagnosis, secondary NPH, a medium ventriculoatrial drain was placed. One week after shunting a clear improvement was seen in her clinical condition. The EEG also showed improvement (8-9/sec alpha activity). Control CT revealed a normal size of the ventricular system. Psychological examination showed significant cognitive improvement. Her good condition continued for 9 months. After this period she developed signs of headache, hypersomnia, epileptic seizures and right-sided hemiparesis. Control CT showed a good functioning drain, but signs of growth of the tumour in the frontal region. She died 6 months later.

Patient 26

This 68-year-old woman had had, 2 months before shunting, a subarachnoid haemorrhage from an aneurysm of the right middle cerebral artery as was established respectively by means of lumbar puncture and arteriography. After the bleeding she recovered well, but approximately 6 weeks later she became disorientated, got urinary incontinence and gait disturbances. The next days she was unable to walk. She got strong rigidity and akinesia and a severe confusional state developed into stupor.

There were no signs of rebleeding but CT showed progressing dilatation of the third and lateral ventricles. Frontal horn index from 0.38 up to 0.50. The RIHSA cisternogram demonstrated ventricular filling and stasis of isotope up to 55 hours but also moderate parasagittal activity. A 48 hour continuous epidural pressure monitoring showed pressure waves. EEG showed diffuse slowing of 4-7 Hz activity. Psychological testing was not possible.

A medium ventriculoatrial drain was placed with immediate result. Six weeks after shunting a remarkable improvement had been obtained as can be seen in the clinical rating scales. Control CT showed decrease in ventricular size (frontal horn index 0.35). The EEG demonstrated 8-9 Hz alpha activity. Six months after shunting the patient was without signs and symptoms.

Patient 27

This 54-year-old man had had, 10 years ago, a brain injury with basal skull fractures and liquorrhoea from which he recovered. Three months before shunting he had had pneumococcal meningitis which had been treated successfully with penicilline. However, 2 months later the patient developed gait disturbance, progressive mental disturbances, urinary incontinence and depressive feelings.

On examination we saw an indolent man with perseverations, mild rigidity and akinesia. He was forgetful and had disturbance in memorizing and he was disorientated as to place. He had a broad-based gait with a tendency to falling backwards. There was strong urinary incontinence. He got anti-epileptic drugs because of focal seizures.

CT showed progressing dilatation of the third, fourth and lateral ventricles with frontal horn index from 0.37 up to 0.44. The EEG demonstrated diffuse slowing and irritative components in the right frontal and temporal regions. A 48 hour continuous extradural pressure monitoring revealed pressure waves.

Because of progressing signs and symptoms of NPH, a medium ventriculoatrial drain was placed 3 months after the onset of the meningitis. Four weeks after shunting a clear improvement in gait, behaviour and mentation was seen, urinary incontinence ceased. Control CT showed normal ventricular size

with signs of bilateral subdural collections. Six weeks later these collections had disappeared spontaneously; frontal horn index was now 0.32. One year after shunting the patient was in a very good clinical condition, which continued during the next years.

Patient 28

This 16-year-old adolescent had had a severe brain injury with frontal impression fractures and concussion six months before shunting. He recovered well, but 5 months after the injury he regressed in mental functions, had headaches, a staggering gait, urinary incontinence and hyperphagia.

On admission we saw a disorientated, confused young man with aggressive behaviour. His gait was broad-based and atactic with hyperactive reflexes and Babinski's signs.

CT showed progressing dilatation of the third and both lateral ventricles (frontal horn index 0.38). There was slight compression of the left frontal horn caused by a porencephalic cyst of the left frontal lobe. The In^{111} DTPA cisternogram disclosed a left frontal porencephalic cyst, but also ventricular filling and stasis of isotope up to 48 hours and a little activity parasagitally. Conclusion: signs of NPH accompanied with a left frontal porencephalic cyst. EEG showed diffuse slowing and irritative components with paroxysmal irritative discharges.

Because of the diagnosis, NPH, a medium ventriculoatrial drain was placed. After shunting the patient improved well, urinary incontinence ceased after some days; his behaviour and mental state improved. Six weeks after surgery his gait was normal but he remained disorientated as to date and had disturbance as to memorizing. Control CT showed decrease in ventricular size (frontal horn index 0.26) and diminution in the size of the porencephalic cyst. Six months after shunting CT showed slit-ventricles. Psychological testing and EEG clearly demonstrated improvement with 8-10/sec alpha activity. One year after shunting there was still moderate disturbance as to memorizing. In the following years there was a progressive improvement of his mental state.

Patient 29

This 58-year-old man had had a severe brain injury with an occipital and petrosal fracture and much blood in the cerebrospinal fluid six months before shunting. Four vessel angiography showed no abnormalities. Four months after the craniocerebral trauma his consciousness was normal, but he suffered from complete disorientation, disturbance in memorizing and in gait and he had also urinary incontinence.

One month later he was admitted to our hospital and we saw a paranoid man who confabulated strikingly. He was also disorientated as to date, place and persons. He had strong impairment in recent and remote memory. He had a staggering and slow gait with a tendency to falling backwards. There was mild rigidity and akinesia and daily urinary incontinence.

CT showed severe dilatation of the lateral, third and fourth ventricles (frontal horn index 0.63). The In^{111} DTPA cisternogram showed ventricular filling and stasis of the isotope up to 48 hours but also parasagittal activity. The EEG showed diffuse slowing with 8-9/sec activity and local delta activity in the left frontotemporal region.

A medium ventriculoatrial drain was placed. Two weeks after shunting a clear improvement was seen in mentation and gait. Urinary incontinence ceased. CT after 1 week demonstrated reduction in ventricular size (frontal horn index 0.57, after 6 weeks the index was 0.47). Psychological testing revealed

dramatic improvement in mental functions. After shunting, the EEG showed 10/sec alpha activity. Three months after surgery the patient had almost completely recovered. After 1 year there was complete recovery.

Patient 30

This 45-year-old man had had, 7 weeks before shunting, a subarachnoid haemorrhage from an aneurysm of the anterior communicating artery which had been diagnosed respectively by means of lumbar puncture and four vessel angiography. Some weeks after the bleeding the patient became disorientated, aggressive with progressive delirium and confusion and urinary incontinence. He would not keep his bed and showed a broad-based atactic gait.

CT showed progressing dilatation of the third and lateral ventricles (frontal horn index 0.53). EEG and cisternogram were not performed. Five weeks after the haemorrhage the aneurysm had been clipped after loss of much cerebrospinal fluid by means of ventricular puncture. In the beginning the patient was mentally better after operation, but then some days later he regressed mentally. This was accompanied with urinary incontinence.

Two weeks later a medium ventriculoatrial drain was placed. One week after that he was in a much better condition, urinary incontinence ceased, mentation and gait improved. CT showed normal ventricular size (frontal horn index 0.37). Three months after shunting the patient was without signs and symptoms.

Patient 31

This 52-year-old woman had had, 8 months before shunting, a subarachnoid haemorrhage from an aneurysm of the left internal carotid artery close to the division of the anterior and middle cerebral artery. This was diagnosed by means of lumbar puncture and four vessel angiography. She recovered well from this haemorrhage with rest motor aphasia and slight right-sided hemiparesis. She was able to walk alone. However, 4 months after the haemorrhage she regressed mentally followed by progressing gait disturbances and total urinary and faecal incontinence.

On admission in our hospital 6½ months after the bleeding we saw a severely confused woman with normal consciousness; she made no (non)verbal contact. There was strong rigidity and akinesia, she smeared with faeces. Pseudobulbar and Babinski's reflexes were present. She had a slight right-sided hemiparesis and severe contractures of arms, legs and hips. She was unable to sit or stand.

CT demonstrated: severe dilatation of the third and both lateral ventricles (index 0.59) and periventricular oedema. The In^{111} cisternogram demonstrated filling and stasis of isotope up to 24 hours. The EEG showed diffuse slowing with local delta activity in the left frontotemporal region.

Because of the severe internal hydrocephalus and the severe clinical condition, we decided to treat the hydrocephalus first despite the presence of an aneurysm. A ventriculoperitoneal shunt was placed. Some days after shunting clear improvement was seen but after 1 week her condition worsened. The cause of this was a disconnection and dysfunction of the peritoneal shunt. After revision of the drain her clinical condition improved well. CT showed decrease in ventricular size resp. 0.52 3 weeks and slit-ventricles 6 months after shunting. The gait disturbance six months later was especially caused by the contractures. The EEG showed alpha 10/sec; slight rest disturbance left frontotemporal. One year after the operation her gait was normal and she was in a very good condition.

Patient 32

This 65-year-old woman had had gait disturbances, vertigo, headaches and loss of memory for about six months. She was apathetic and showed no interest in her environment. Her husband was struck by her infantile behaviour. Patient had been treated for hypertension; 5 years ago she had had a subarachnoid haemorrhage when being treated with anticoagulants for cardial infarction.

On admission we saw an apathetic aggressive woman with strong disturbance in memorizing and recent memory. She had strong rigidity and akinesia, her gait was broad-based with spastic atactic components and a history of falling. Plantar reflexes were extensor, pseudobulbar reflexes were present. There was no urinary incontinence.

CT showed: normal third and fourth ventricle but moderate dilatation of both lateral ventricles (index 0.40) and slight cortical atrophy. Carotid angiography showed signs of diffuse severe arteriosclerosis. The In^{111} DPTA cisternogram demonstrated ventricular filling and stasis up to 48 hours with some parasagittal activity. EEG demonstrated lack of synchronization with many beta activities. A 48 hour continuous epidural pressure monitoring revealed no pressure waves.

A medium ventriculoatrial drain was placed. Postoperatively, the patient had febris e.c.i. which was treated with antibiotics. One month after shunting her gait showed slight improvement. Control CT showed decrease of ventricular size with slit-ventricles. One month after that she complained of a headache. Control CT and angiography revealed no signs of subdural collections. Because of temperature and signs of sepsis (staphylococcus aureus), the shunt had to be removed 6 months after shunting. There was no apparent clinical improvement in patient's condition.

Patient 33

This 49-year-old woman had had change in mentation for two years beginning with slowing of mental and physical activity, reduced spontaneity, indifference towards her environment and later also progressive impairment in memorizing and forgetfulness. She also had had gait disturbances but no urinary incontinence for the last six months. Before she had been a healthy, active woman. There was no prior history of head injury, meningitis or (cerebro)-vascular disease. Thyranon medication for 18 months because of hypothyroidism was without result.

On admission we saw a very apathetic depressive woman with strong rigidity and akinesia, she had a masklike face. The staggering gait was broad-based and atactic with Babinski's signs. There was strong impairment of recent memory and concentration. Cholesterol and T4 were normal. CT showed moderate dilatation of the third and lateral ventricles (index 0.40) and also cortical atrophy. The In^{111} DTPA cisternogram demonstrated ventricular filling and stasis of isotope up to 24 hours, but also parasagittal activity. EEG showed diffuse irritative components alpha 9-11/sec. A 48 hour continuous epidural pressure monitoring showed pressure waves.

Although the diagnosis NPH was debatable we decided to give the patient the benefit of the doubt and a medium ventriculoatrial drain was placed. After shunting the patient complained of a headache which ceased after 1 week. Control CT showed decrease in ventricular size (frontal horn index 0.34). Three weeks after that she again complained of a headache, was more disorientated and got grand mal epileptic seizures. Angiography and CT revealed two-sided subdural collections and overshunting. The shunt was ligated and after 6 weeks the collections had vanished. Because in the meantime ventricular size had increased, a high pressure ventriculoatrial shunt was

placed 1 month after ligation. After this the patient was in good condition. Control CT after 2 years showed slit-ventricles.

Patient 34

This 62-year-old woman had undergone biopsy of the cingulate gyrus 15 months before shunting. An astrocytoma grade III had been diagnosed and treated with radiation. She was in a good condition for 8 months. After that she got forgetful, got gait apraxia and urgency for micturition.

On admission we saw a very apathetic woman with mild rigidity and depressive feelings. There was strong impairment of recent memory and concentration. She had evident gait apraxia with a tendency to falling backwards. There was spastic paraparesis R > L with exaggerated reflexes; she needed to touch objects when walking.

CT showed no signs of tumour but progressing dilatation of the third and lateral ventricles (index 0.40). In^{111} DTPA cisternogram showed filling and stasis of isotope up to 24 hours with some parasagittal activity. EEG demonstrated 9/sec alpha activity and theta and irritative activities in the left frontotemporo-basal region. A 48 hour continuous epidural pressure monitoring showed pressure waves.

A medium ventriculoatrial drain was placed. After shunting her condition improved very well. Control CT demonstrated decrease of ventricular size (index 0.33). The EEG showed less theta and irritative activities. Her good condition continued for 16 months after shunting. Then she became more apathetic with headaches, diplopia, left-sided hemiparesis and urinary incontinence. CT showed a good functioning drain but also signs of growth of the tumour invading the corpus callosum. She died 6 months later.

Patient 35

This 71-year-old woman had had a brain injury with basal skull fractures and a right parietal fracture 2 months before shunting. She had lost consciousness for about an hour. Some weeks after the craniocerebral trauma the patient got disorientated as to date and place. She deteriorated progressively with loss of memory and slight delirium developed with urinary incontinence and gait apraxia.

Six weeks after the injury we saw a confused woman with broad-based atactic gait, she needed support in walking. There was mild rigidity and akinesia. Reflexes were exaggerated with plantar extensor reflexes. She had cerebellar dysarthria.

CT showed progressing dilatation of the third and lateral ventricles and periventricular oedema with concussion left frontotemporal, index 0.46. In^{111} DTPA showed filling and stasis of isotope up to 48 hours. EEG showed diffuse slowing alpha 8-9/sec. A 48 hour continuous extradural pressure monitoring revealed pressure waves.

A medium ventriculoatrial drain was placed. Control CT demonstrated decrease in ventricular size (index 0.34). After the operation urinary incontinence ceased and her condition improved. Her good clinical condition continued during the next years. Psychological examination showed improvement of mental functions.

Patient 36

This 65-year-old woman underwent a hypophysectomy in January 1980 because of

a chromophobe adenoma. One year later she slowly regressed mentally, followed by progressing gait disturbance and urinary incontinence.

On admission to our hospital 18 months after the hypophysectomy we saw a very obese woman who was apathetic and had strong impairment of memory. She was disorientated as to date and place and she was unable to walk because of spastic paraparesis and akinesia with rigidity. During her admission the level of consciousness lowered to hypersomnia.

CT showed progressing dilatation of the third and both lateral ventricles (index up to 0.54). CT with enhancement and cerebral angiography revealed no signs of a tumour. The In^{111} DTPA cisternogram demonstrated ventricular filling and stasis of isotope up to 48 hours. A 48 hour continuous epidural pressure monitoring showed pressure waves. The EEG showed diffuse slowing with 8-9 Hz alpha activity mixed with 6-7 Hz activities.

A medium ventriculoatrial drain was placed. However, 2 revisions had to be done because of obstruction of the ventricular catheter and dysfunction of the cardial catheter. After shunting, the level of consciousness increased and during the next months a gradual improvement was observed. Control CT showed decrease in ventricular size resp. index 0.40 after 2 weeks and 0.37, 2 months after shunting. Six months after shunting she was in a very good condition despite her obesitas which prevented a normal gait. Psychological examination showed improvement of mental functions.

Patient 37

This 62-year-old man had had mental regression for about 4 years, gait disturbance for 2 years and urinary incontinence, too, for 1 year. No prior history of cerebral trauma, meningitis or bleeding was known. At the age of 46 he had had a myocardial infarction.

On admission we saw a depressive man with compulsive weeping and pseudobulbar reflexes. He was disorientated as to date and place and had strong impairment of recent and remote memory. He showed perseverations. He had a staggering and slow gait with a tendency to falling backwards. There was mild akinesia and rigidity with pyramidal signs of the legs and daily urinary incontinence.

CT showed dilatation of the third and lateral ventricles (index 0.47) with periventricular oedema, but also some cortical atrophy. The In^{111} DTPA cisternogram showed ventricular filling and stasis of isotope up to 48 hours. The EEG showed diffuse slowing with $7\frac{1}{2}$-8 Hz activity.

Because of the diagnosis, idiopathic NPH, a medium ventriculoatrial drain was placed. Because of obstruction of the cardiac catheter, revision had to be done. After shunting, a gradual improvement was seen in his clinical condition. Urinary incontinence ceased, gait improved, as did his intellectual functions. Control CT showed decrease of ventricular size (index 0.44). The EEG showed 9 Hz alpha activities 3 months after surgery. Psychological examination demonstrated improvement of mental functions.

Patient 38

This 69-year-old woman had a 3 year history of mental regression and gait disturbance before she got headaches and right-sided hemiparesis with aphasia on May 15, 1981. CT showed an internal hydrocephalus and an infarction in the left thalamic region. Lumbar puncture was not performed. There was no prior history of cerebral trauma or meningitis. She had had hypertension for 5 years. Because of progressing deterioration as to the hydrocephalus, the patient was taken to our hospital 6 weeks later.

On admission we saw a woman who was anxious, apathetic and sometimes also aggressive. She had a slight hemiparesis R with motor aphasia. She was disorientated as to place, time and person. There was strong rigidity of arms and legs with pyramidal reflexes. She had urinary incontinence, truncal ataxia and frontal ataxia which made walking impossible.

CT showed dilatation of the third and lateral ventricles (index 0.46) with periventricular oedema, but also some cortical atrophy and signs of an old infarction in the left thalamic region. The In^{111} DTPA cisternogram demonstrated ventricular filling and stasis of isotope up to 48 hours, but also some activity in the parasagittal regions. The EEG showed diffuse slowing with 6-8 Hz activity and 1-2 Hz activity in the L frontotemporal region. Carotid angiography (L) demonstrated signs of arteriosclerosis with a maximum of M I way.

Because of the diagnosis NPH, a medium ventriculoatrial drain was placed. After shunting, a gradual improvement was observed; urinary incontinence ceased, her mental functions improved. Control CT showed decrease of ventricular size (index 0.34), but also signs of a subdural collection R frontotemporal. Control CT 2 weeks later showed that this collection had vanished. The EEG showed 8-9 Hz activities. The clinical improvement continued for 15 months. Then she had several times left-sided hemiparesis which was more serious in the leg than in the arm (TIA's) and had a number of falls. She was afraid and refused to walk. She had pseudobulbar signs and gradually a frontal lobe syndrome developed under suspicion of vascular aetiology. Control CT showed no changes; drain function was intact.

Patient 39

This 72-year-old woman had had progressing gait disturbance for about 18 months followed by mental regression and urinary incontinence. No prior history of cerebral trauma, bleeding or meningitis was known. In the past, patient had been treated with antihypertensives. Last year the blood pressure was normal (145/80 mmHg).

On admission we saw a kind, obese and apathetic woman with impairment of recent memory. She was disorientated as to place and time. She had strong rigidity of the legs; the gait was broad-based with a tendency to falling backwards and she needed support in walking. She had complete urinary incontinence.

CT showed dilatation of third, fourth and lateral ventricles (index 0.59), but also some cortical atrophy. Carotid angiography showed signs of diffuse arteriosclerosis with 30-50% narrowing of both cervical internal carotid arteries. The In^{111} DTPA cisternogram showed ventricular filling and stasis of isotope up to 48 hours, but also moderate activity in the parasagittal regions. The EEG demonstrated diffuse slowing with 8-9 Hz activity mixed with many 5-7 Hz activities. Psychological testing showed a total IQ: 75. A 48 hour continuous epidural pressure monitoring revealed pressure waves.

Because of the diagnosis, idiopathic NPH, a medium ventriculoatrial drain was placed. Some days after surgery a clear improvement was seen in her clinical condition. Urinary incontinence ceased; she walked without support and her mental functions also improved. Control CT 2 weeks after shunting showed decrease in ventricular size (frontal horn index 0.48). The EEG showed 9-10 Hz activities and had improved. Psychological testing had also improved. She had a very good clinical condition during the next 22 months, as can be seen in the clinical rating scales. Then she developed her old signs and symptoms because the drain dit not function properly. After revision a left-sided hemiparesis was seen. Some days later she was in a coma and died of cardiac-cerebrovascular failure.

Patient 40

This 56-year-old woman had got difficulty in walking, urinary incontinence and forgetfulness with disorientation about 2 months before shunting. Six years before that she had had a TIA with hypertension and since that time she had been treated with antihypertensives. PEG six years ago showed no abnormalities, cerebral angiography showed signs of diffuse arteriosclerosis. No prior history of meningitis or cerebral trauma was known.

On admission we saw a very confused woman sho had confabulations; she was disorientated as to place, date and person. There was urinary incontinence. She had a frontal ataxia with a tendency to falling backwards. Pseudobulbar signs were present and also pyramidal signs of the legs.

CT showed dilatation of the lateral, third and fourth ventricles (frontal horn index 0.51) and also slight cortical atrophy. Th In^{111} DTPA cisternogram demonstrated ventricular filling and stasis up to 48 hours with moderate parasagittal activity. The EEG showed diffuse slowing of 8 Hz activity with 1-2½ Hz activity in the left frontotemporal region.

Because of the diagnosis, idiopathic NPH, a ventriculoatrial drain was placed. One week after shunting a remarkable improvement was seen in her clinical condition. Control CT showed decrease of ventricular size (index 0.45). The EEG showed 8½-9 Hz activities. Her clinical condition was very good as can be seen in the clinical rating scores.

Patient 41

This 73-year-old man had got difficulty in walking, followed by mental regression and urinary incontinence about 1 year before shunting. He had several falls. No prior history of meningitis or (cerebro)vascular disease was known.

On admission we saw a very confused aggressive man, who showed confabulations and who was disorientated as to place, date and person. There was urinary incontinence. He needed support in walking. The gait pointed to a frontal ataxia with a tendency to falling backwards. Pseudobulbar signs were present and also mild rigidity and akinesia. Reflexes were exaggerated with plantar extensor reflexes.

CT showed severe dilatation of the lateral and third ventricles (frontal horn index 0.58) but also moderate cortical atrophy. The In^{111} DTPA cisternogram demonstrated ventricular filling and stasis up to 48 hours. The ECG showed signs of an old anteroseptal myocardial infarction. The EEG showed diffuse slowing of 7-8 Hz activity with 1½-2½ Hz activities in both frontotemporal regions.

Because of the diagnosis, idiopathic NPH, a ventriculoatrial drain was placed. Four weeks after shunting a remarkable improvement was seen in his clinical condition, with progressing improvement during the following months. Control CT showed decrease of ventricular size (index 0.53). The EEG showed 8-9 Hz activities.

Patient 42

This 20-year-old man had had, 13 months before shunting, a severe head injury with concussion and subdural haematoma in the right frontotemporal region followed by a spontaneous improvement.

However, during about 6 months before shunting the patient had remained in a stationary situation. He was apathetic, had confabulations and perseverations. He was disorientated as to date, place and person. There was a slight

spastic quadriplegia L > R with hyperactive reflexes and Babinski's signs. He had urinary incontinence and also strong rigidity and akinesia with a mask-like face. He needed support in walking; his gait was broad-based atactic.

CT demonstrated dilatation of the third and both lateral ventricles with periventricular oedema (frontal horn index 0.46). The In^{111} DTPA cisternogram showed ventricular filling and stasis up to 48 hours, but also a moderate activity in the parasagittal regions. The EEG demonstrated 9 Hz activities.

Because of the diagnosis, posttraumatic NPH, a medium ventriculoatrial drain was placed. Control CT showed decrease of ventricular size (index 0.43). The EEG showed 9-10 Hz activities. Two months later the patient was in a much better condition and he improved stadily in the following months.

Patient 43

This 77-year-old man had had progressing instability in walking with a history of falling since 2 years. During the last year his family had observed forgetfulness, emotional lability and urinary incontinence. No prior history of brain injury, meningitis or cerebrovascular disease was known. During the last year he had used Aldomet because of hypertension.

On examination we saw a man who was apathetic but at times also paranoid-aggressive with confabulations and disorientation as to date. He had disturbance in memorizing. His gait was broad-based atactic with hyperreactive and extensor reflexes of the legs. He had mild rigidity and akinesia and pseudobulbar reflexes. There was regular urinary incontinence.

CT showed dilatation of the third and lateral ventricles with periventricular oedema (index 0.48) but also moderate cortical atrophy. The In^{111} DTPA cisternogram demonstrated ventricular reflux and stasis up to 48 hours but also moderate activity in the parasagittal region. The EEG showed diffuse slowing with 7 Hz activities and 3-5 Hz activities in the right frontotemporal region.

Because of the diagnosis, idiopathic NPH, a ventriculoperitoneal drain (with revision of the abdominal drain) was placed. Three weeks after the operation an improvement was seen in his clinical condition which continued for the next 12 months as can be seen in the clinical rating scales. Control CT showed no decrease of ventricular size. The EEG had improved with 8 Hz activities. In a hot summer, well over one year after shunting, he came in a confusional state suffering from dehydration. He died after some days.

Patient 44

This 52-year-old woman had had a brain injury with concussion and basal skull fractures 4 months before shunting. She improved well, but 2 months later she regressed and was confused and disorientated. CT showed progressing ventricular dilatation. For this reason she was sent to our hospital.

On admission we saw a disorientated confused woman with nonsensical talk. Her gait was broad-based and atactic with hyperreflexia and extensor reflexes. She was aggressive and had daily urinary incontinence.

CT showed dilatation of the third, fourth and both lateral ventricles with periventricular oedema (frontal horn index 0.46). The In^{111} DTPA cisternogram showed ventricular filling and stasis up to 48 hours with a little activity in the parasagittal regions. A 48 hour epidural pressure monitoring demonstrated pressure waves.

Because of the diagnosis, post-traumatic NPH, a medium ventriculoatrial shunt was placed. Some days after the operation a remarkable improvement was seen which progressed during the next months. Control CT showed decrease of

ventricular size (index 0.39). Psychological testing had also improved.

Patient 45

This 69-year-old man had had signs of progressing dementia with confusion and disorientation for 2 years and since 1 year also gait disturbances with falling and urinary incontinence. Because of tremor and akinesia antiparkinsonian medicaments were given, but without success. Prior history had disclosed diabetes mellitus having existed for more than 25 years and hypertension. He used antihypertensives.

On examination we saw an apathetic hypokinetic man with a tremor of the right hand and rigidity. He was confused and uttered nonsensical talk with perseverations. Sometimes he was aggressive. His gait was broad-based and atactic with short steps. There were hyperreflexia, psuedobulbar reflexes and Babinski's signs. He had daily urinary incontinence.

CT showed dilatation of the third and both lateral ventricles with periventricular oedema (frontal horn index 0.45); cortical atrophy was absent. The In^{111} DTPA cisternogram showed ventricular filling and stasis up to 48 hours but also activity in the parasagittal region. The EEG demonstrated diffuse slowing with 7-8½ Hz activities and 2-3 Hz activities in the left frontotemporal region.

Because of the diagnosis, idiopathic NPH, a ventriculoatrial drain was placed. Control CT showed decrease of ventricular size with frontal horn index 0.34. The EEG remained unchanged. After the operation the clinical situation remained the same as can be seen in the clinical rating scales.

Patient 46

This 65-year-old man had had, since 5 years, progressing signs of forgetfulness, slowing of mental and physical activity and reduced spontaneity. For the last 2 years he had suffered from impairment of memorizing and orientation but also from gait disturbances with falling and since 6 months also from urinary incontinence. He was taking antihypertensives. There was no prior history of head injury, meningitis or (cerebro)vascular disease.

On admission we saw a very apathetic, depressive and confused man with confabulations and nonsensical talk. RR 200/90 mmHg. His staggering gait was broad-based atactic with a tendency to falling backwards. There was hyperreflexia with extensor reflexes R > L and daily urinary incontinence. There was mild akinesia and rigidity.

CT showed a severe dilatation of the third and lateral ventricles with periventricular oedema and without cortical atrophy (frontal horn index 0.52). The In^{111} DTPA cisternogram demonstrated no ventricular filling; there clearly was parasagittal activity after 24-48 hours. Epidural pressure monitoring during 48 hours revealed pressure waves. The EEG showed 8-9 Hz activities with 2 Hz activities in the left frontotemporal region.

Because of the diagnosis, idiopathic NPH, a ventriculoperitoneal drain was placed. After shunting a remarkable improvement was seen. Control CT showed decrease of ventricular size (index 0.44) and slit-ventricles after 1 year. The EEG remained unchanged. Psychological testing showed improvement too.

Patient 47

This 51-year-old woman had had depressive feelings with slowing of mental and physical acitivity for 2 years. Four months before shunting her family had

observed progressing forgetfulness and instability in walking with a history of falling. Finally, there was urinary incontinence and confusion. No history of brain injury, meningitis or (cerebro)vascular disease was known.

On admission we saw a depressive, apathetic woman with strong akinesia and rigidity and with a masklike face. She confabulated and was disorientated as to date and place. There were severe disturbances in recent and remote memory. She had a staggering, short-stepped and atactic gait with a tendency to falling backwards. Pseudobulbar reflexes were present with hyperreflexia and extensor reflexes of the legs. She had regular urinary incontinence.

CT showed a dilatation of the third and both lateral ventricles with periventricular oedema and without cortical atrophy (frontal horn index 0.50). The In^{111} DTPA cisternogram demonstrated ventricular filling and stasis of isotope up to 48 hours. The EEG showed diffuse slowing with $7\frac{1}{2}$-$8\frac{1}{2}$ Hz and 2-3 Hz activities in the left temporal region. Psychological investigations demonstrated confabulations, perseverations and severe disturbances in memorizing (IQ 60).

Because of the diagnosis, idiopathic NPH, a medium ventriculoperitoneal drain (with revision of the abdominal drain) was placed. Some days after shunting a remarkable improvement was seen. Control CT showed decrease of ventricular size (index 0.30). The EEG had improved with 9 Hz alpha activity and also psychological investigations (IQ 109) showed clear improvement.

Patient 48

This 75-year-old man had had progressing gait disturbances with a history of falling since 3 years. Since 2 years there had also been complaints of forgetfulness and disorientation. The last 4 months he was more aggressive and had urinary incontinence. There was no prior history of brain injury or meningitis. Four years ago hypertension had been diagnosed and 1 year ago he had had a TIA with right-sided hemiparesis.

On examination we saw an aggressive-paranoid man with confabulations and perseverations; he was disorientated as to date and place and had severe disturbances in recent memory. He had rigidity in arms and legs and a masklike face. His staggering gait was short-stepped and atactic with a tendency to falling backwards. Sometimes he had urinary incontinence. There were hyperreactive reflexes with Babinski's signs and pseudobulbar reflexes.

CT revealed dilatation of the third and both lateral ventricles with periventricular oedema but also moderate cortical atrophy (frontal horn index 0.50). The EEG showed diffuse slowing with 8 Hz activities. The In^{111} DTPA cisternogram showed ventricular filling and stasis of the isotope up to 48 hours but also moderate activity in the parasagittal region after 24 hours. A 48 hour epidural pressure monitoring revealed no pressure waves.

Because of the diagnosis, idiopathic NPH, a ventriculoperitoneal drain was placed. After shunting his clinical condition improved gradually as can be seen in the clinical rating scales. Control CT showed decrease in ventricular size (index 0.48). The EEG showed $8\frac{1}{2}$-$9\frac{1}{2}$ Hz activities.

Patient 49

This 78-year-old woman had had gait disturbances with a history of falling since 18 months. Because of her masklike face, bradykinesia, rigidity and tremor of the hands, the diagnosis of Morbus Parkinson had been made. Treatment with amantadine, however, was without success. Since 1 year there had been complaints of forgetfulness and disorientation and since six months there had been urinary incontinence. She had taken phenytoin because of focal

epileptic seizures 3 years ago. No history of brain injury, meningitis or (cerebro)vascular disease was known.

On examination we saw an apathetic depressive woman with a masklike face and bradykinesia. She was disorientated as to date and place with strong impairment of recent memory and concentration. She had evident gait apraxia with short-stepped, spastic movements and a tendency to falling backwards. There were tremors of the hands with strong rigidity. There was a symmetrical paraparesis of a combined pyramidal and extrapyramidal character and pseudobulbar reflexes. She needed to touch objects while walking. There was daily urinary incontinence.

CT demonstrated signs of an old infarction in the region of the right medial and posterior cerebral artery and dilatation of the third and both lateral ventricles (frontal horn index 0.41). There was periventricular oedema and no signs of cortical atrophy. The In^{111} DTPA cisternogram showed ventricular filling and stasis of the isotope up to 48 hours. The EEG revealed 8-9 Hz alpha activities with 1-2½ Hz activities in the left frontotemporal region. A 48 hour epidural pressure monitoring revealed pressure waves.

Because of the diagnosis, idiopathic NPH, a ventriculoperitoneal drain was placed. After shunting a remarkable improvement was seen. Control CT showed decrease of ventricular size with frontal horn index 0.34. The EEG had improved with faster activities of 9-10 Hz. Psychological testing showed improvement too.

Patient 50

Three months before shunting this 24-year-old woman had been found with respiratory arrest and absent blood pressure. After resuscitation respiratory function restored spontaneously after approximately 15 minutes. Afterwards, the patient remained in a coma. Full investigation revealed no aetiology for this event. Particularly, there were no indications for a subarachnoid haemorrhage. Spinal fluid and cerebral CT showed no abnormalities. After 6 weeks with the patient in a coma vigil state, CT was performed again. Now CT showed dilatation of the third and lateral ventricles with periventricular oedema (frontal horn index 0.42). The patient was sent to our department for treatment of the hydrocephalus.

On admission we saw a young woman in a coma vigil state with quadriplegia spastica and strong rigidity in arms and legs. The ocular discs were pale. There were no signs of increased intracranial pressure. The In^{111} DTPA cisternogram showed no ventricular filling of the isotope; after 48 hours there was great activity in the skull, spread over the cortical and parasagittal regions. CT remained unchanged. The EEG showed diffuse slowing with 2-5 Hz activities and no reaction to flash-light. A 48 hour epidural pressure monitoring demonstrated pressure waves with ICP 15-22 mmHg.

We decided to give the patient the benefit of the doubt and a medium ventriculoperitoneal drain was placed. Despite a functioning drain, there were no changes in her clinical situation after shunting as can be seen in the clinical rating scales. EEG and CT showed a similar picture before and after shunting.

Patient 51

This 75-year-old man had had progressive mental regression with disturbances in memorizing, disorientation, confusion and aggressive feelings since 3 years. Since 1 year he had had gait disturbances with a history of falling and urinary incontinence. No prior history of brain injury, meningitis or

(cerebro)vascular disease was known. He had had chronic bronchitis with emphysema for over 20 years.

On examination we saw a seriously confused man with confabulations and nonsensical talk and with disorientation as to date, place and person. He was aggressive and had urinary and faecal incontinence. He needed support in walking. His gait was broad-based atactic with a tendency to falling backwards. There was strong rigidity in arms and legs. He had paraparesis of a combined pyramidal and extrapyramidal character.

CT demonstrated dilatation (with progression) of the third and lateral ventricles (frontal horn index 0.47 up to 0.51). There was also moderate cortical atrophy. The In^{111} DTPA cisternogram showed ventricular filling and stasis up to 48 hours. The EEG showed diffuse slowing with 5-7 Hz activities and 2-3 Hz activities in both frontotemporal regions but also FIRDA. A 48 hour epidural pressure monitoring showed no pressure waves. Psychological testing was not feasible.

Because of the diagnosis, idiopathic NPH, a medium ventriculoperitoneal drain was placed. During the first weeks after shunting a moderate improvement of his clinical condition was seen. CT showed decrease of ventricular size (frontal horn index 0.45). The EEG had improved a little with 7-8 Hz activities. However, after 6 weeks he regressed again while having a functioning drain. In the nursing home he had epileptic seizures and 3 months after shunting he died with signs of cardiac-respiratory failure.

Patient 52

This 67-year-old man had had gait disturbances for 3 years and since six months a history of falling and also progressive forgetfulness and disorientation. The last 2 months there was urinary incontinence, too. He had used antihypertensives for 2 years. No prior history of brain injury, meningitis or (cerebro)vascular disease was known.

On examination we saw a friendly man with a staggering short-stepped gait; he used crutches and had a tendency to falling backwards. He had strong impairment of recent memory with disorientation as to date and place. There was hyperreflexia with Babinski's signs and pseudobulbar signs and also mild rigidity and akinesia. RR 200/115 mmHg.

CT showed dilatation of the third and both lateral ventricles (frontal horn index 0.48) with periventricular oedema but also signs of old infarctions in the left hemisphere and moderate cortical atrophy. The In^{111} DTPA cisternogram showed ventricular filling and stasis of the isotope up to 48 hours but also some activity in the parasagittal region after 24 and 48 hours. A 48 hour epidural pressure monitoring demonstrated pressure waves up to 28 mmHg. The EEG showed diffuse slowing with 7 Hz activities and $1\frac{1}{2}$-$2\frac{1}{2}$ Hz activities in the left frontotemporal region and also FIRDA.

Because of the diagnosis, idiopathic NPH, a medium ventriculoperitoneal drain was placed. After shunting slight improvement was seen. Control CT and EEG remained unchanged. Five months later, drain revision was done because of signs of a partial drain dysfunction. Now a low pressure ventriculoperitoneal drain was placed. Despite a functioning drain the patient's clinical condition did not change during the following 12 months as can be seen in the rating scales. Psychological testing showed no improvement. CT showed a frontal horn index of 0.38 but the EEG demonstrated more FIRDA and more slowing, too.

Patient 53

This 63-year-old woman had had gait disturbances with a history of falling but also progressing forgetfulness, depressive feeling and impairment of recent memory for 2½ years. Since 2 months there had been urinary incontinence, too. She had been treated for legulcers caused by diabetes mellitus and for hypertension. No prior history of brain injury, meningitis or cerebrovascular disease was known.

On examination we saw a paranoid, depressive woman with a masklike face and oral dyskinesias. She had perseverations and was desorientated as to date. There was a staggering short-stepped gait with spastic paraparesis. She had pseudobulbar reflexes and hyperreflexia of the legs with Babinski's signs. Sometimes she had urinary incontinence.

CT showed dilatation of the third, fourth and both lateral ventricles with periventricular oedema but also moderate cortical atrophy (frontal horn index 0.48). The In^{111} DTPA cisternogram showed ventricular filling and stasis of the isotope up to 48 hours with a little activity in the parasagittal region. A 48 hour epidural pressure monitoring demonstrated no pressure waves. The EEG showed diffuse slowing wiht 7-7½ Hz activities and FIRDA.

Because of the diagnosis, idiopathic NPH, a medium ventriculoperitoneal drain was placed. No apparent improvement was seen in her clinical condition. Control CT showed decrease of ventricular size (index 0.42). The EEG after shunting remained unchanged. Psychological testing did not show improvement.

Patient 54

This 76-year-old man had had gait difficulty with a staggering gait since 18 months and since 1 year progressing forgetfulness with inconstant confusion and disorientation. Finally, he had urinary incontinence, too. No prior history of brain injury, meningitis or (cerebro)vascular disease was known.

On admission we saw a friendly old man, RR 180/115 mmHg. He was disorientated as to date and had impairment of recent memory. He had a staggering short-stepped gait with a tendency to falling backwards; he used a cane. Reflexes were exaggerated with extensor reflexes and pseudobulbar reflexes were present. The ECG showed signs of an old cardiac infarction. He had been treated with antihypertensives.

CT revealed dilatation of the third, fourth and both lateral ventricles with periventricular oedema but also moderate cortical atrophy (frontal horn index 0.44). The In^{111} DTPA cisternogram demonstrated ventricular filling and stasis of isotope up to 48 hours. A 48 hour epidural pressure monitoring showed no pressure waves. The EEG showed diffuse slowing with 7½-8 Hz activities.

Because of the diagnosis, idiopathic NPH, a medium ventriculoperitoneal drain was placed. After shunting there was no improvement as can be seen in the clinical rating scales. Control CT showed decrease of ventricular size (index 0.35). The EEG demonstrated 7-8 Hz activities. Psychological examination did not show improvement.

Patient 55

This 70-year-old woman was known with hypertension for 5 years. Since 2 years she had had gait disturbances with a history of falling and had needed support in walking. For the last 18 months there had been slowing of mental and physical activity, depressive feelings and desinterest in her environment. She had progressing forgetfulness and inconstant disorientation. For the last

months she had had urinary incontinence, too. No prior history of brain injury, meningitis or cerebrovascular disease was known.

On examination we saw a paranoid-aggressive woman with depressive feelings. She was disorientated as to date and had impairment in memorizing. She had strong rigidity and akinesia. She needed support in walking and her gait was short-stepped, spastic and atactic with a tendency to falling backwards. Plantar reflexes were extensor and pseudobulbar reflexes were present.

CT showed dilatation of the third and both lateral ventricles with periventricular oedema but also moderate cortical atrophy (frontal horn index 0.43). The In^{111} DTPA cisternogram demonstrated ventricular filling and stasis up to 48 hours. The EEG showed 8½-9 Hz activities with irritative components in both frontotemporal regions and also FIRDA.

Because of the diagnosis, idiopathic NPH, a medium ventriculoperitoneal drain was placed. Some days after operation, a remarkable improvement in her clinical condition was seen. Control CT showed decrease of ventricular size (index 0.27). The EEG after shunting had improved, too, with 9 Hz activities and without FIRDA. Psychological testing had shown improvement too.

Patient 56

This 56-year-old man had had a brain injury with bifrontal concussion and subdural haematoma 1 year before shunting. After this he improved well and had a normal ventricular size on CT 4 months after the accident. Six months after the accident, however, he regressed. He became apathetic, had gait difficulties and finally he was confused and had urinary incontinence. Control CT showed ventricular dilatation (frontal horn index 0.45) and after lumbar puncture had been performed his gait was better for some days.

On admission we saw an apathetic but also aggressive and confused man with hypersomnia and disorientation as to date. His gait was broad-based and atactic with spastic paraparesis and hyperreflexion L > R. There was urinary incontinence. CT showed dilatation of the third, fourth and both lateral ventricles with periventricular oedema (frontal horn index 0.46). The In^{111} DTPA cisternogram demonstrated ventricular filling and stasis of isotope up to 48 hours. A 48 hour epidural pressure monitoring revealed no pressure waves. The EEG showed 8-9 Hz activities and 1-3 Hz activities in both frontotemporal regions R > L.

Because of the diagnosis, post-traumatic NPH, a medium ventriculoperitoneal drain was placed. Some days after shunting a remarkable improvement was seen. Control CT showed decrease of ventricular size (frontal horn index 0.33). The EEG showed 9-9½ Hz activities and had improved. Psychological testing also showed improvement.

Patient A

This 65-year-old woman had had a subarachnoid haemorrhage 4 months before shunting. An aneurysm of the communicans anterior artery was found by means of arteriography. After good improvement she regressed again after 2 months.

CT showed progressing dilatation of the third and both lateral ventricles with periventricular oedema (index 0.44). The In^{111} DTPA cisternogram showed ventricular filling and stasis up to 48 hours. A 48 hour epidural pressure monitoring demonstrated pressure waves. The Doppler-LP test was positive.

Because of the diagnosis, secundary NPH, a ventriculoatrial drain was placed. Nevertheless the patient died after 2 weeks because of pneumonia and renal failure.

Patient B

This 69-year-old man had had progressing gait disturbances, mental deterioration and urinary incontinence. Twenty years ago he had had a severe brain injury with fractures of the skull base.

CT showed a giant internal hydrocephalus with dilatation of the third and lateral ventricles (index 0.71). The In^{111} DTPA cisternogram showed no ventricular filling and a normal cisternogram. A 48 hour epidural pressure monitoring demonstrated pressure waves. The Doppler-LP test was positive.

Because of the diagnosis, late post-traumatic NPH, a medium ventriculoatrial drain (with revisions) was placed. However, the patient died within 2 weeks after the last revision because of cardiovascular-respiratory failure.

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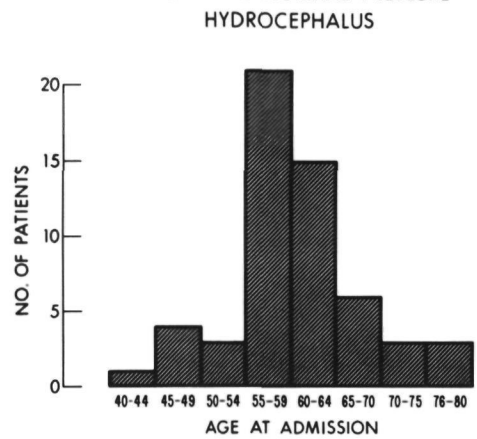
FIGURES


"IDIOPATHIC NORMAL-PRESSURE"
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NO. OF PATIENTS
20
15
10
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40-44
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55-59
60-64
65-70
70-75
76-80
AGE AT ADMISSION

Fig. I

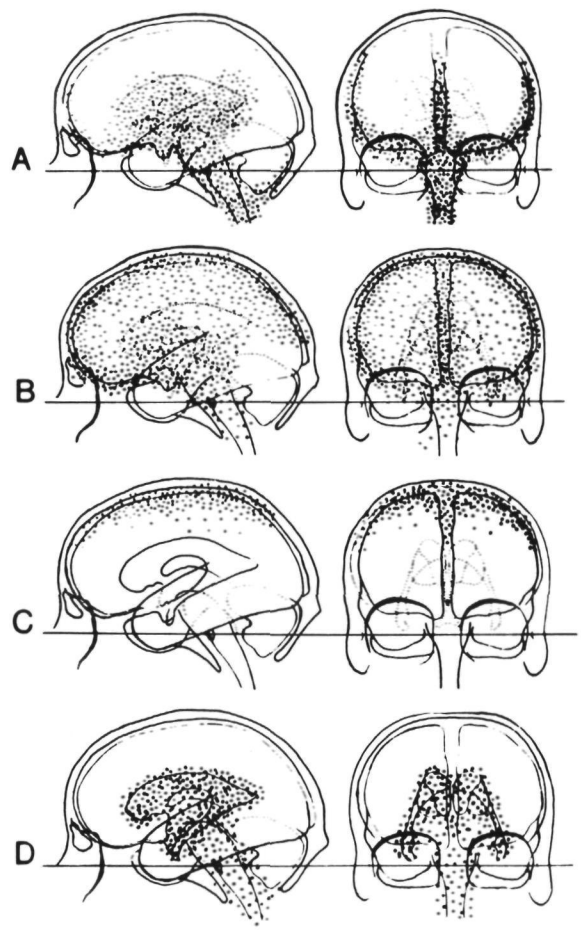
A
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Fig. II

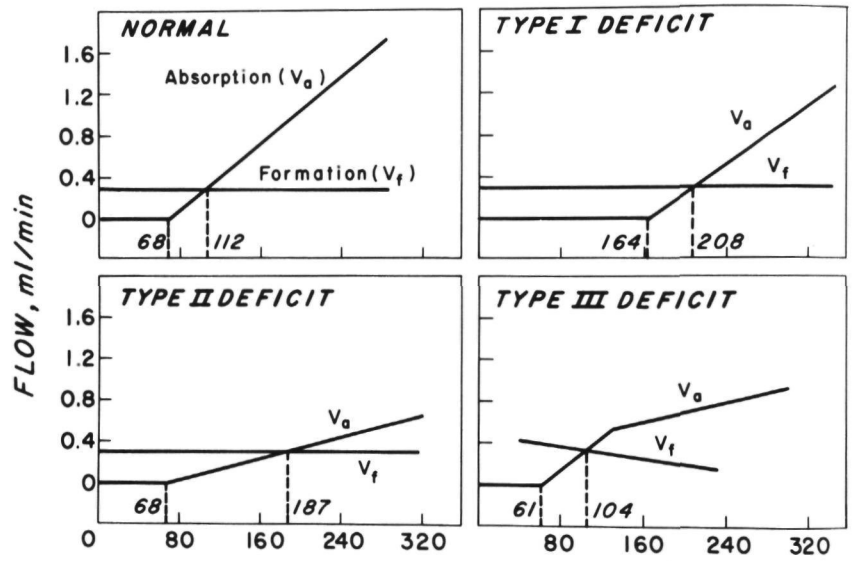
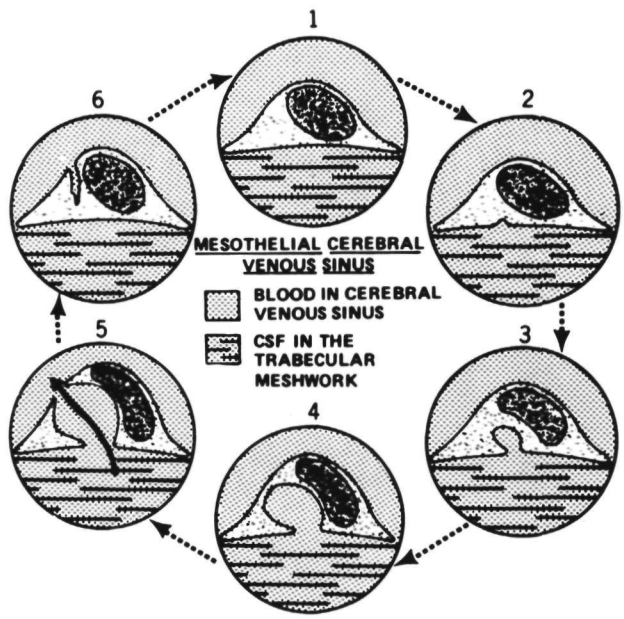

NORMAL
Absorption (V_a)
Formation (V_f)
68
112
TYPE I DEFICIT
V_a
V_f
164
208
TYPE II DEFICIT
V_a
V_f
68
187
TYPE III DEFICIT
V_a
V_f
61
104
1.6
1.2
0.8
0.4
0
80
160
240
320
FLOW, ml/min
OUTFLOW (PERFUSION) PRESSURE, mmCSF

Fig. III


1
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MESOTHELIAL CEREBRAL VENOUS SINUS
BLOOD IN CEREBRAL VENOUS SINUS
CSF IN THE TRABECULAR MESHWORK

Fig. V

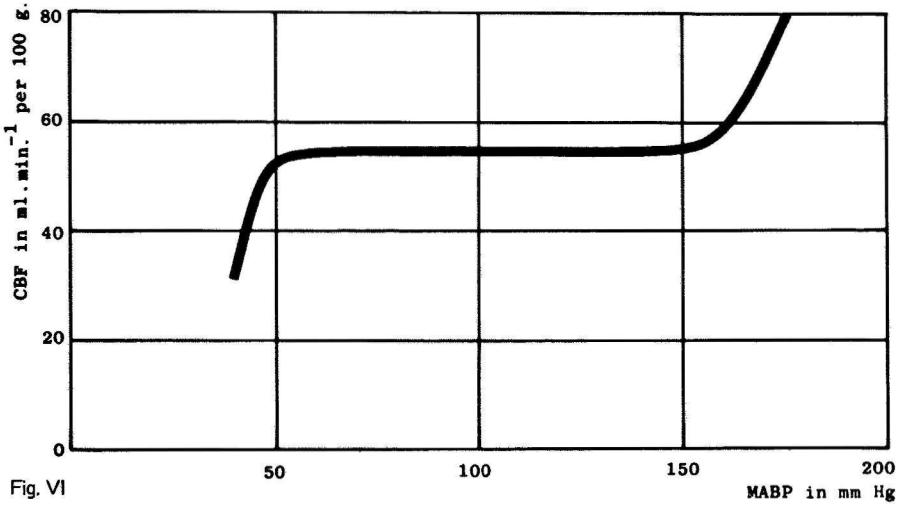
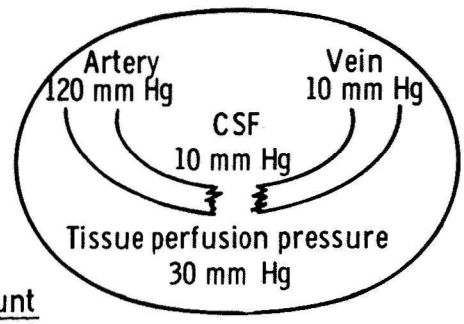
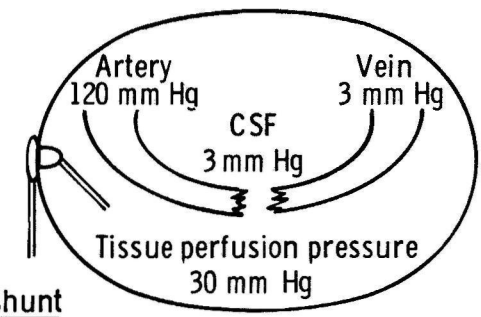


Fig. VI



preshunt



postshunt

Pressure differential:

(Tissue perfusion − venous pressure)

Fig. VII

Preshunt : 20 mm Hg

Postshunt : 27 mm Hg

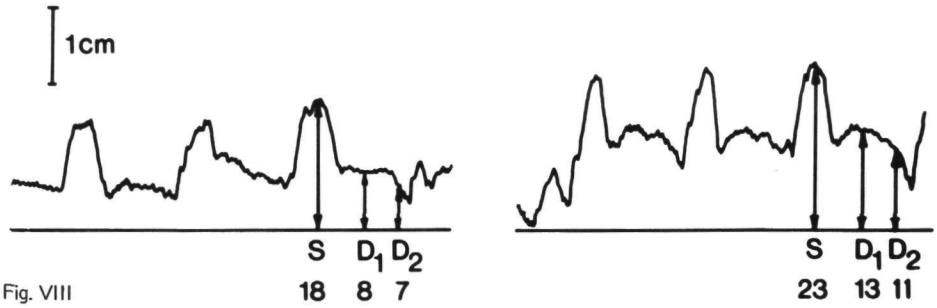


Fig. VIII

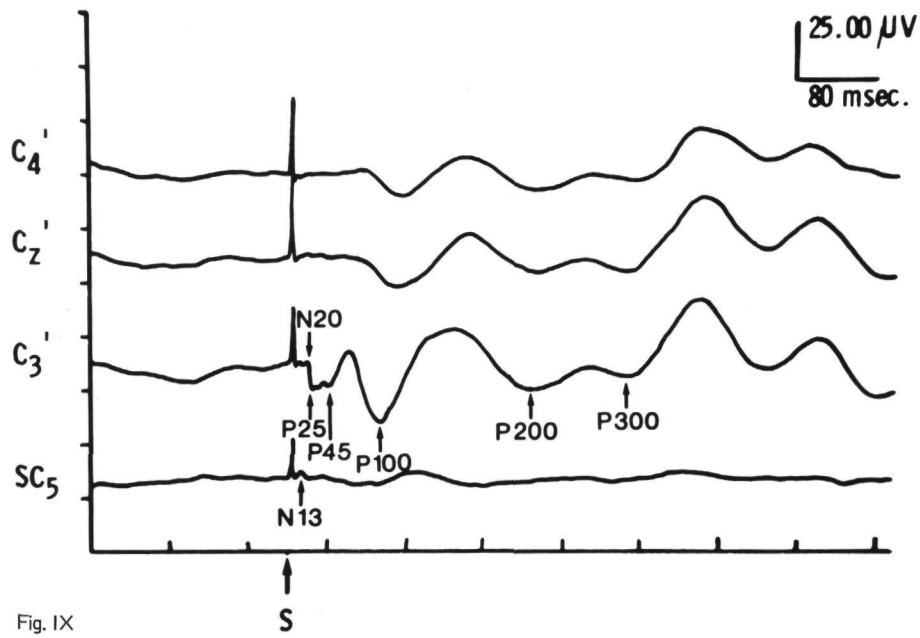


Fig. IX

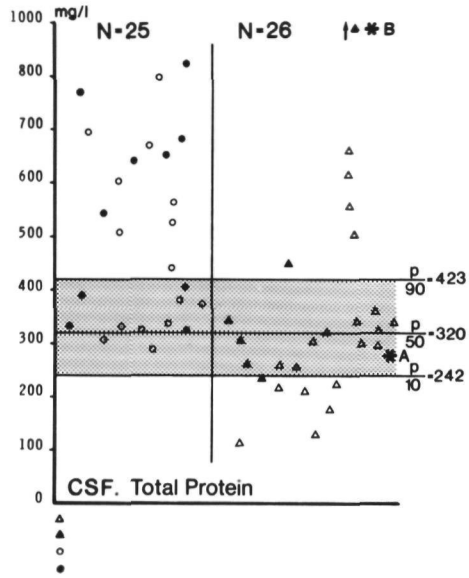
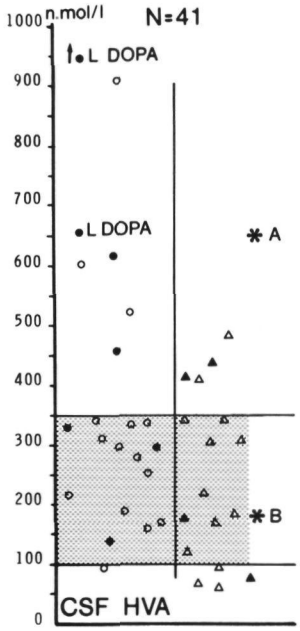


Fig. X



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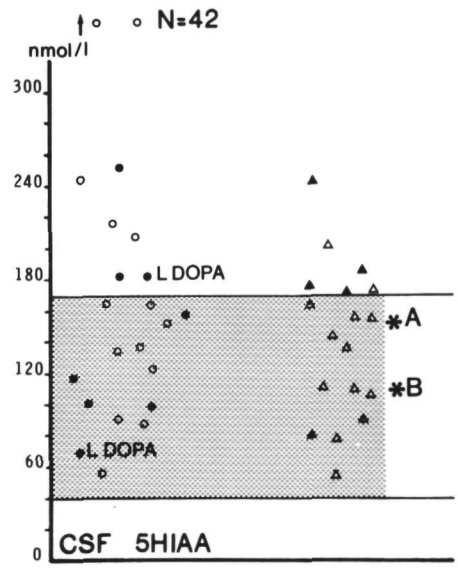


Fig. XIII

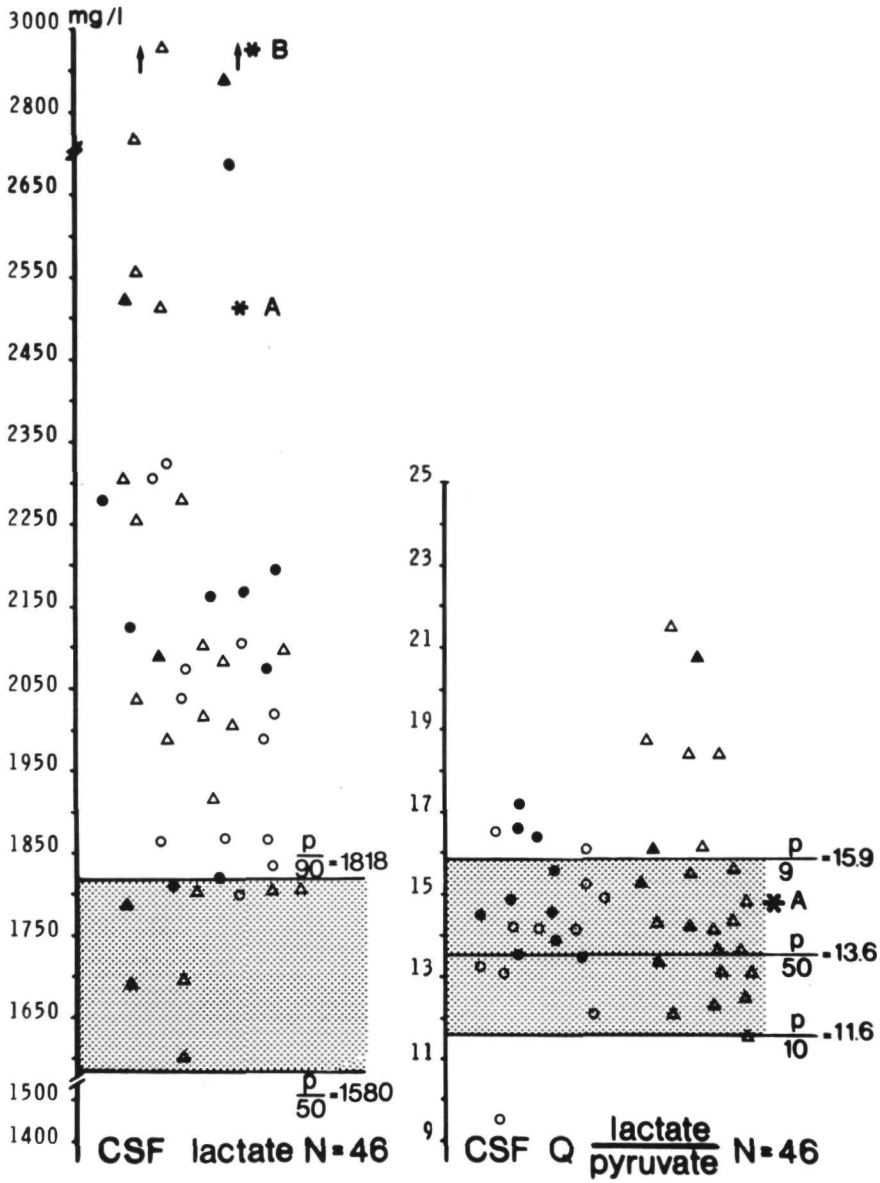

3000 mg/l
2800
2650
2550
2450
2350
2250
2150
2050
1950
1850
1750
1650
1500
1400
B
A
p/90 -1818
p/50 -1580
CSF lactate N=46
25
23
21
19
17
15
13
11
9
p/9 -15.9
A
p/50 -13.6
p/10 -11.6
CSF Q lactate/pyruvate N=46

Fig. XI

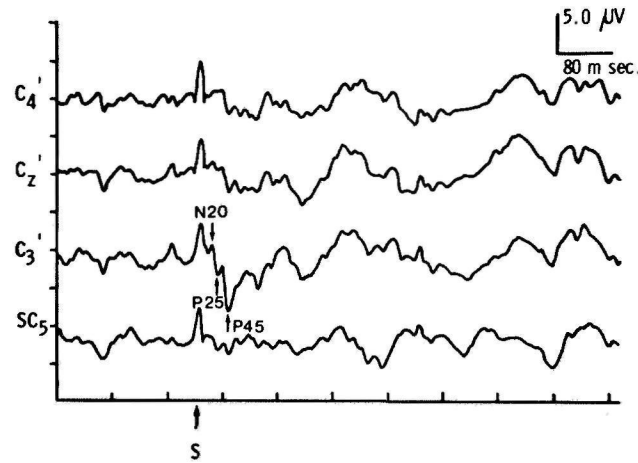


Fig. XIV

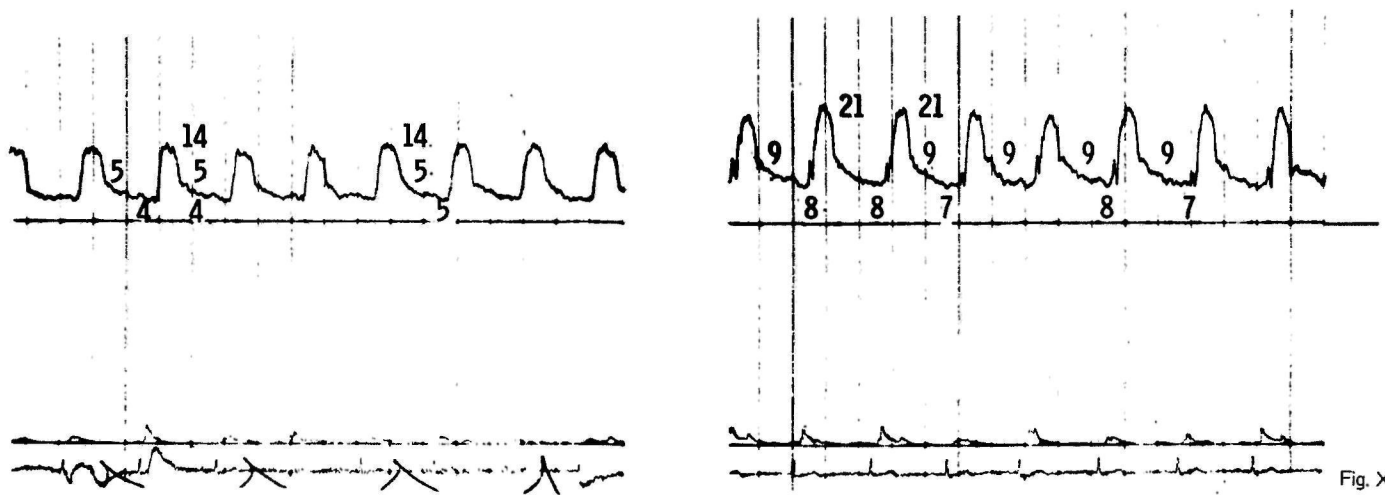
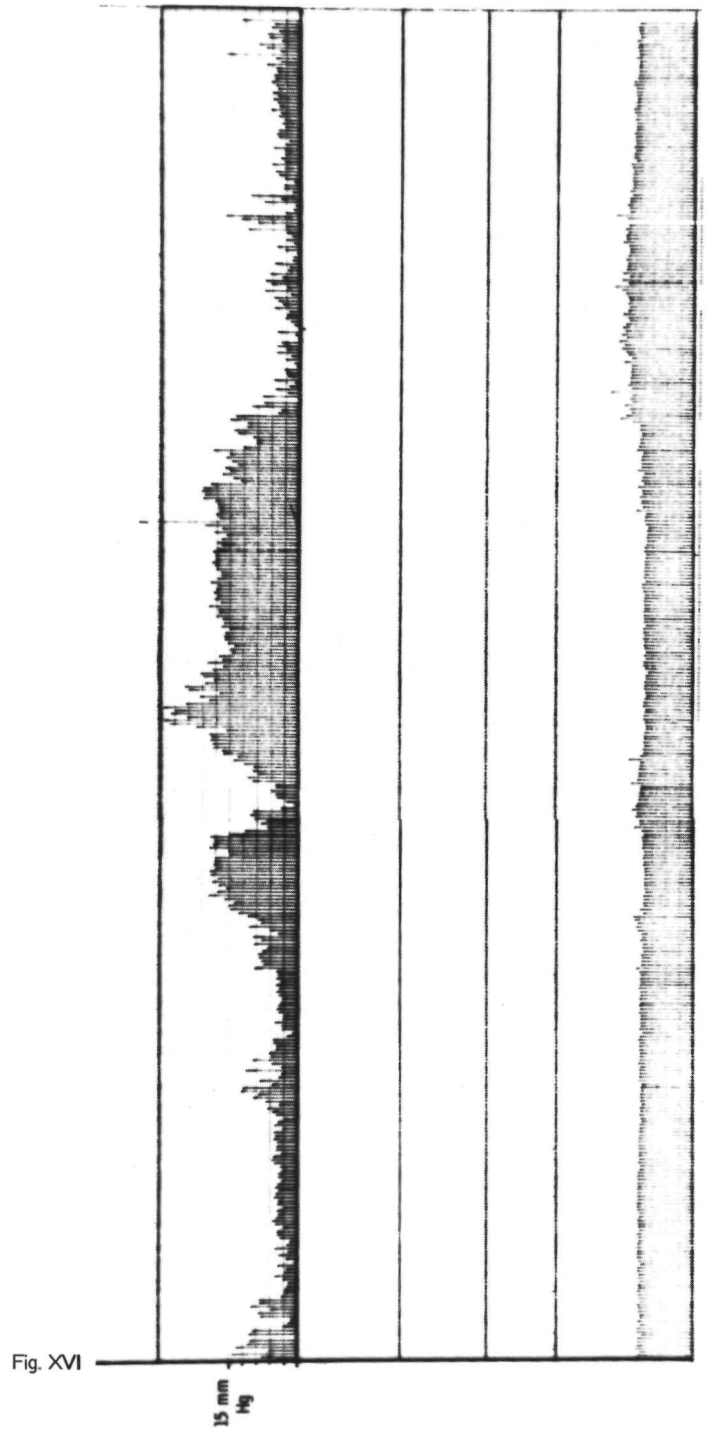


Fig. XV



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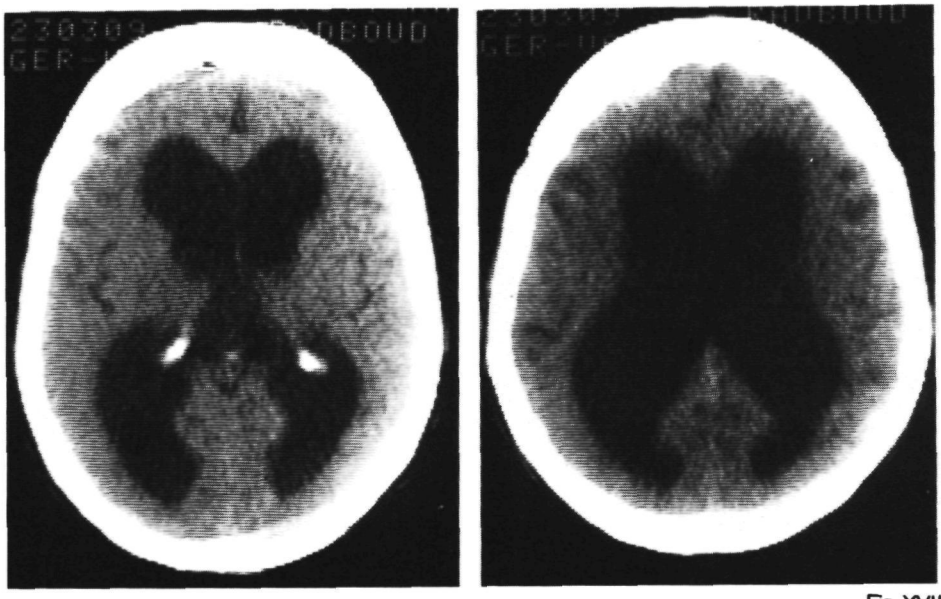


Fig. XVII

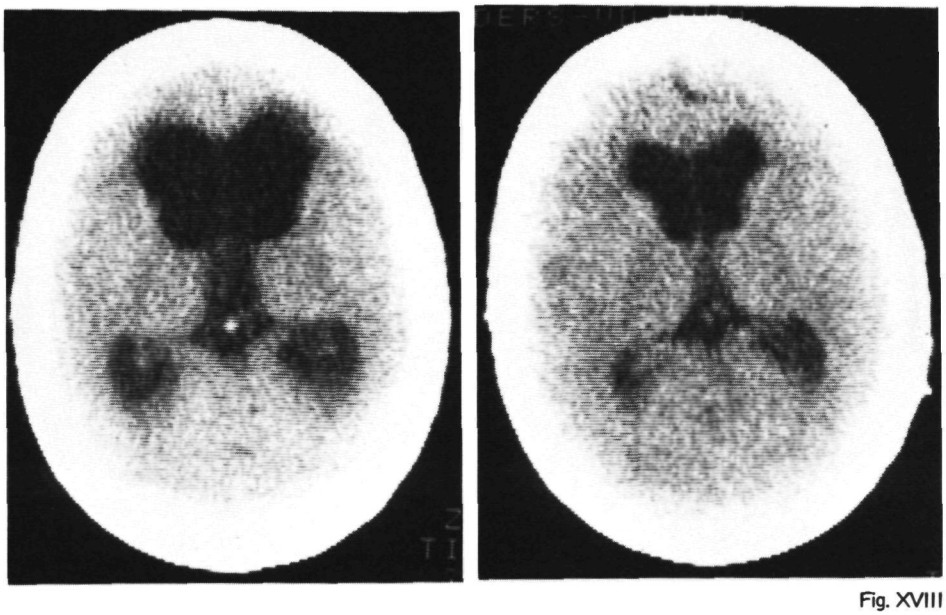


Fig. XVIII

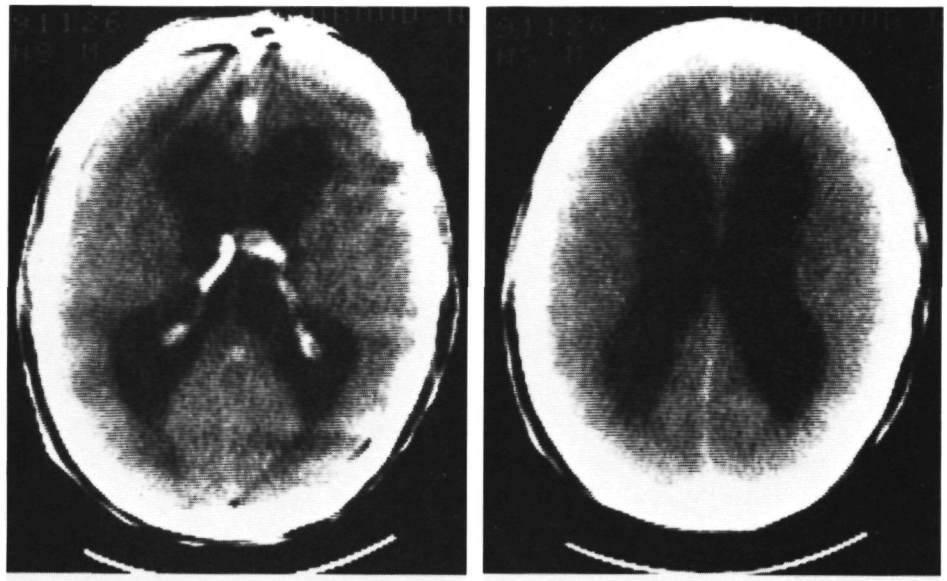


Fig. XIX

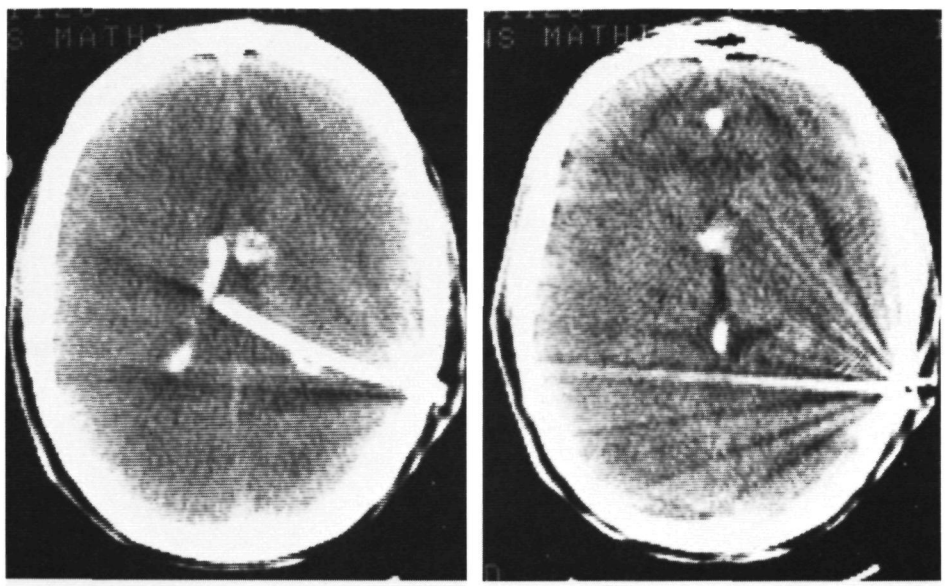


Fig. XX

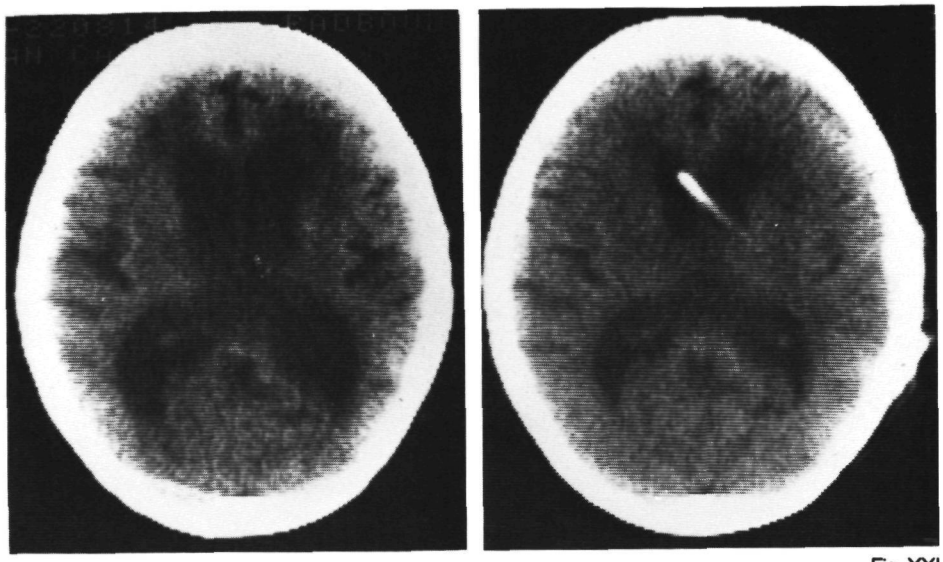


Fig. XXI

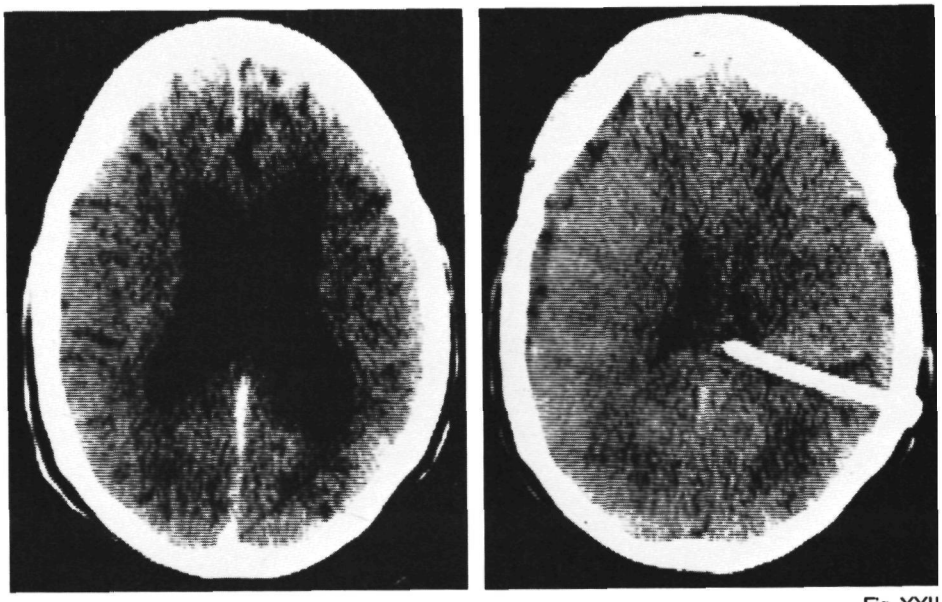
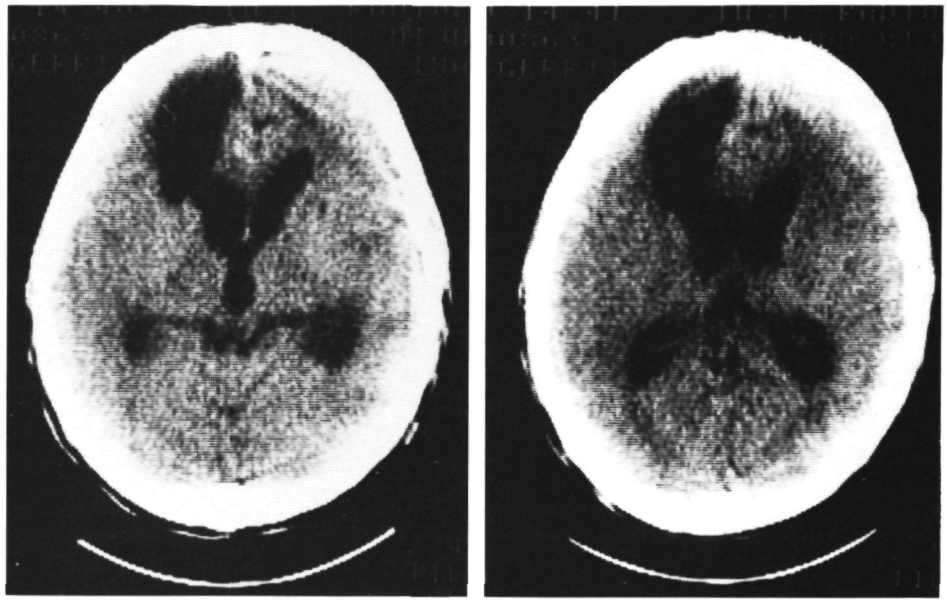
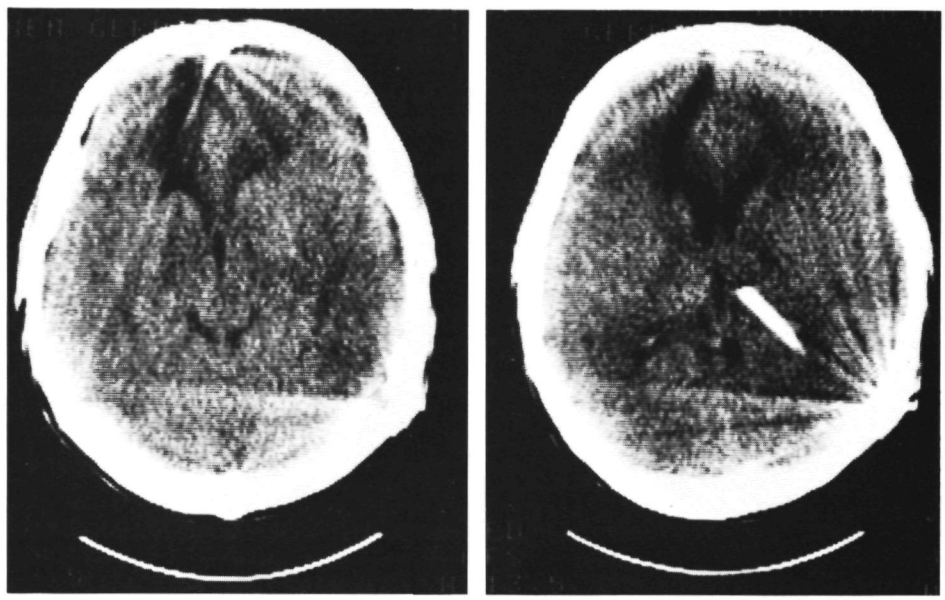


Fig. XXII



A



B

Fig. XXIII

LEGENDS TO THE FIGURES

Fig. I:

Age at time of admission of patients with diagnosis of idiopathic NPH (Katzman 1977).

Fig. II:

Schematic drawing of normal radioisotope cisternography (A-C) and of the "representative" cisternography picture of NPH (D).
A: distribution of radiopharmaceutical 4 hrs after LP.
B: distribution at 24 hrs: rather homogeneous spread over subarachnoid spaces around the brain.
C: at 48 hrs.
D: radioactivity is seen in the CSF spaces around the spinal cord and brainstem up to the tentorial opening and in the ventricular system (4 hrs after LP, at 48 hrs).

Fig. III:

Pressure-absorption relationships observed in patients with and without obstruction to CSF pathways. Opening pressures and pressures at which formation equals absorption are designated in italic numbers.
The rate of formation is constant with regard to CSF pressure, over the pressure range indicated, but CSF absorption increases linearly with pressure. The intercept at 112 mm (normal) indicates the pressure at which formation and absorption are equal.
At a CSF pressure of 68 mm (normal), zero absorption would be expected (from Cutler, Page et al. 1968).

Fig. IV:

The cerebrospinal fluid circulation (from The Ciba Collection of Medical Illustrations, Vol. 1 The nervous system, plate 21, 1962).

Fig. V:

Proposed dynamic system of transcellular channels or pores through which CSF flows from subarachnoid space to venous sinus down a pressure gradient. Stage 5 represent the temporary transmesothelial channel and the arrows represent bulk overflow of CSF (from Tripathi and Tripathi 1974).

Fig. VI:

Relationship between CBF and MABP (according to Lassen 1959 and Strandgaard 1978).

Fig. VII:

Schematic drawing concerning the influence of the tissue perfusion pressure on CBF. Pre- and post-shunt pressure differentials (according to Salmon 1971 and Brock 1976).

Fig. VIII:

Schematic drawing of Doppler-HTG of the right common carotid artery with the systolic value S and two diastolic values D_1 and D_2. The left side shows the blood flow velocity before and the right side after LP (patient no. 10).

Fig. IX:

Example of the wave form of a normal SSEP.

Figs. X, XI, XII and XIII:

Representation of lumbar CSF values of total protein, lactate, ratio lactate-pyruvate, HVA and 5-HIAA respectively.
△= non-idiopathic NPH patient improved after shunting
▲= non-idiopathic NPH patient not improved
○= idiopathic NPH patient improved after shunting
●= idiopathic NPH patient not improved

Fig. XIV:

Example of the wave form of a SSEP in a patient with NPH (patient no. 21).

Fig. XV:

Example of Doppler-HTG curve of the right common carotid artery (patient no. 55). The left side shows the blood flow velocity before and the right side after LP. The curve below is the ECG.

Fig. XVI:

Example of a positive epidural monitoring (patient no. 13). Speed trendrecorder: 1 gauge/1½ minute. Below: curve of cardiac frequency. Peakpressure exceeded 15 mmHg during a period longer than 10 minutes and was registered between 03.00 and 06.00 hrs.

Fig. XVII:

Example of CT scanning in a patient with NPH (patient no. 39) with symmetrical dilatation of both lateral ventricles and the third ventricle.

Fig. XVIII:

CT scanning in patient no. 47. The left side shows CT before and the right side after shunting. Before shunting there is periventricular oedema; there is obvious reduction of ventricular size after shunting.

Fig. XIX:

CT scanning in patient no. 24, before shunting.

Fig. XX:

CT scanning in the same patient 2 weeks after shunting shows slit-ventricles.

Fig. XXI:

CT scanning in patient no. 55 (70 years) with signs of cortical atrophy. The left side shows CT before and the right side after shunting.

Fig. XXII:

CT scanning in patient no. 27 (54 years). The left side shows CT before and the right side after shunting. After shunting there is decrease of ventricular size with signs of subdural collections (left more than right).

Fig. XXIII:

CT scanning in patient no. 28 (16 years).
A: before shunting: dilatation of the third and lateral ventricles with slight compression of the left frontal horn caused by a porencephalic cyst of the left frontal lobe.
B: after shunting: decrease of ventricular size and diminution in the size of the porencephalic cyst.

DANKWOORD

Vanwege hun - deels onmisbare - hulp, advies en gezelschap tijdens de totstandkoming van dit proefschrift wil ik de volgende personen (voor zover het promotiereglement dit toestaat) en afdelingen hartelijk danken.

- Het Instituut voor Neurologie (hoofd: Prof.Dr. B.P.M. Schulte), in het bijzonder:
  -de Afdeling Klinische Neurofysiologie (hoofd: Prof.Dr. S. Notermans). Mijn speciale dank gaat uit naar Mevr. M.W.M. Godding-Cuyten en Mevr. E. Nas.
  -de Verpleegafdeling, met name van N2O.
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  -de Foto- Film- en Tekenafdeling, op de heren N.G.J. Dijkstra en J.H.G. Wijnen heb ik nooit tevergeefs een beroep gedaan.
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- De Afdeling Neuroradiologie (hoofd: Prof.Dr. H.O.M. Thijssen) van het Instituut voor Radiodiagnostiek.
- De Afdeling Nucleaire Geneeskunde (hoofd: Dr. F.H.M. Corstens).
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CURRICULUM VITAE

De schrijfster van dit proefschrift werd geboren op 13 december 1944 te Veldhoven.

Na het behalen van het einddiploma HBS-B aan het Thorbecke Lyceum te Arnhem in 1962 begon zij haar studie in de geneeskunde aan de Katholieke Universiteit te Nijmegen. In 1968 werd het doctoraal-examen afgelegd en op 10 april 1970 het arts-examen.

Van 1 april 1970 tot 1 april 1975 volgde zij de opleiding tot zenuwarts (hoofdvak: Neurologie) in het Sint Radboudziekenhuis te Nijmegen (opleiders: Prof.Dr. J.J.G. Prick en Prof.Dr. S.J. Nijdam). De aantekening Klinische Neurofysiologie werd behaald onder leiding van Prof.Dr. S.L.H. Notermans en Drs. P.J.H. Bernsen.

Sinds haar inschrijving in het Specialisten Register in 1975 is zij werkzaam als staflid van het Instituut voor Neurologie (hoofd: Prof.Dr. B.P.M. Schulte) van het Sint Radboudziekenhuis te Nijmegen.

STELLINGEN

behorende bij het proefschrift

NORMAL PRESSURE HYDROCEPHALUS

The Doppler-LP test and other selection criteria for shunting

In het openbaar te verdedigen
op 25 juni 1986
des namiddags te 2.00 uur precies

door

H.C. Schoonderwaldt

I

Onderzoek naar normal pressure hydrocephalus dient als een vast onderdeel van de diagnostiek bij dementie te worden beschouwd.

II

De klachten en verschijnselen van normal pressure hydrocephalus zijn het gevolg van een autoregulatiestoornis in het cerebrale vaatbed vanuit het carotis systeem.

III

Met de "Doppler-LP test" is het mogelijk vast te stellen welke patienten met normal pressure hydrocephalus in aanmerking komen voor een shunt-operatie.

IV

Cisternografie met isotopen is van weinig waarde voor de selectie van patiënten met normal pressure hydrocephalus voor een shunt-operatie.

V

De leeftijd van een patiënt met normal pressure hydrocephalus is geen contra-indicatie voor het uitvoeren van een shunt-operatie.

VI

Juiste interpretatie van de "visual evoked potentials" is alleen mogelijk na een volledig neurologisch èn oogheelkundig onderzoek.

VII

Bij patienten met aspecifieke klachten en verschijnselen van het centrale en perifere zenuwstelsel is het zinvol de diagnose hypothyreoïdie in de differentiele diagnose te betrekken.

VIII

Patiënten, die zonder bekende risicofactoren vóór hun vijftigste jaar een cerebrovasculair accident krijgen, dienen onderzocht te worden met de zogenaamde methionine-belastingstest om het bestaan van heterozygotie voor homocystinurie aan te tonen of uit te sluiten.

IX

Het optreden van de "post-stroke hypertension" moet beschouwd worden als een adaptatiefenomeen en dient dan ook niet behandeld te worden met antihypertensieve middelen.

X

Bij het zoeken naar de oorzaak van aangeboren mentale retardatie bij jongens mag onderzoek naar het bestaan van het "fragile X syndrome" niet ontbreken. Het opsporen van deze chromosomale afwijking is van grote sociaal-geneeskundige betekenis.

XI

Bij het voorschrijven van geneesmiddelen aan bejaarden dient steeds rekening te worden gehouden met de vraag in hoeverre het risico van vallen hierdoor wordt vergroot.

XII

De afwezigheid van achillespeesreflexen bij (hoog)bejaarde patiënten is geen onderdeel van het fysiologische verouderingsproces.

XIII

Het is niet belangrijk hoe oud men wordt, maar wel hoe men oud wordt.

XIV

Er worden te weinig obducties verricht.

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